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SUGAR-BEET PRODUCTION IN CALIFORNIA

W. W. ROBBINS AND CHARLES PRICE

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W. W. ROBBINS[1] AND CHARLES PRICE[2]

INTRODUCTION

THIS CIRCULAR deals principally with cultural practices for the sugar beet—both the methods that are old and well established in California and those that are new and promising. It discusses the behavior of the sugar beet under different climatic and soil conditions; and the influence of various environmental factors upon the crop, as expressed in yield of root, yield of top, sucrose (sugar) percentage, and purity. The commoner diseases of the sugar beet in California are briefly described.

The sugar beet responds surprisingly well to good care and to proper and timely treatment. Not uncommonly, two adjoining fields of sugar beets, occupying soil of equal fertility, show a difference of as much as 5 or 6 tons to the acre because of some one outstanding operation, such as good seed-bed preparation, superior thinning, or timely irrigation. Some recently developed practices, such as ridge planting, mechanical blocking, and thinning with two operations instead of one, have given good results in certain districts and might well be tried elsewhere. Although the grower may not be justified in completely changing over to a new cultural practice, he should, if he hopes to obtain increased yields of sugar from an acre at minimum cost, be willing to try it on a limited acreage.

In California, we should look forward to the development of experienced sugar-beet growers—farmers who direct a special and studied effort to the crop, adjusting it as an integral part of their farming system, and who provide themselves with the proper implements so that the various operations may be effective and timely. We should anticipate the development of sugar-beet districts, having in mind the proper adaptation of crops and systems of farming to soil and climatic conditions. Only thus can lands be utilized economically and an industry created which is profitable to both processor and grower.

Often a grower plants too large a percentage of his acreage to beets. This tendency defeats a proper rotation of crops, and frequently leads to unsatisfactory returns. It is better to grow 20 tons to the acre on 40 acres of land than 15 tons to the acre on 80 acres of land.

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A prospective grower of sugar beets in any locality should, first of all, consult his county farm advisor and also a representative of the sugar company or companies operating in his district. Each sugar company has

Fig. 1.—Sugar-beet districts of California. The numbers indicate the location of sugar-beet factories. 1, Clarksburg, Amalgamated Sugar Co.; 2, Manteca, Spreckels Sugar Co.; 3, Tracy, Holly Sugar Corp.; 4, Alvarado, Holly Sugar Corp.; 5, Spreckels, Spreckels Sugar Co.; 6, Betteravia, Union Sugar Co.; 7, Oxnard, American Crystal Sugar Co.; 8, Santa Ana, Holly Sugar Co.

a local general manager or agricultural superintendent and one or more field men. The main agricultural offices of the sugar companies operating in California are located as follows:

The Amalgamated Sugar Company, Clarksburg
American Crystal Sugar Company, Oxnard
Holly Sugar Corporation, Stockton and Santa Ana
Spreckels Sugar Company, Sacramento and Salinas
Union Sugar Company, Betteravia

Always, the grower should keep in close contact with and coöperate with the agricultural staff of the sugar company. The sugar beet is handled as a contract crop. The company with which the grower contracts will necessarily use discrimination in selection of land, as regards its crop history, soil fertility, water available for irrigation, and distance from the delivery dump; also, the company will consider the fitness and experience of the grower, his farming equipment, and other qualifications. The sugar beet requires considerable outlay to the acre in order to bring it to harvest. No farmer should undertake a large acreage without duly considering all the problems involved. On some types of soil the beets may be so inferior that the cost of sugar extraction is excessive. Accordingly, sugar companies decline to contract for sugar beets to be grown on such land. Moreover, the sugar company in any locality attempts to establish and maintain a sugar-beet territory, by which is meant a territory in which the sugar beet is a basic crop in the rotation and in which a group of farmers each year raises enough to insure a certain tonnage, at a profit to themselves. Since certain soils may become infested with diseases that are carried on harvested beets or in dump dirt, the company exercises the right to decline contracts involving such land in order to protect other growers.

THE PLACE OF THE SUGAR BEET IN DIVERSIFIED FARMING

Where climatic and soil conditions are suitable, the sugar beet is well adapted to diversified agriculture. In certain old and well-established farming districts, both European and American, a root crop such as the sugar beet or the mangel is nearly always used in the rotation system. There are several fundamental reasons: (1) the sugar beet is a deep-rooted, tilled crop, alternating well with shallow-rooted, nontilled crops; (2) it requires intensive cultivation, which cleans the land of weeds, and thus increases the yields of subsequent crops by reason of improved tilth and clean soil; and (3) it provides tops, pulp, and molasses for feeding, which stimulates a local stock-feeding industry, which in turn provides a source of farm manure. Moreover, sugar beets furnish a cash crop of high value to the acre and guarantee the farmer, through the contract method of operation, a market for his product.

The sugar beet is not "hard on the land" except as almost any crop is harmful if grown continuously on the same area for years. Nor is the sugar beet a "heavy feeder," in taking relatively large amounts of mineral nutrients from the soil (table 1). Generally speaking, as compared with other common crops, it uses relatively large amounts of potassium but less nitrogen and phosphorus. In fact, the usual experience is that where beets enter into the crop-rotation system, the beet crop improves the yield of many other kinds of crops that follow it. Data from many farming sections prove that this is the case.

The Huntley Agricultural Experiment Station, Montana, has reported the results of a thirteen-year rotation experiment, among which are those showing the influence of beets in the rotation upon succeeding crops. For this period of thirteen years, oats continuously grown averaged 37.9 bushels to the acre, and in rotation with sugar beets, 82.0 bushels to the acre; potatoes continuously averaged 153.8 bushels to the acre, and in rotation with sugar beets, 220.0 bushels; wheat continuously 21.7 bushels, and in rotation with sugar beets, 33.8 bushels; corn continuously 28.5 bushels, and in rotation with sugar beets and oats, 41.3 bushels.

Nor do sugar beets "poison the land." Where they have been grown continuously on the land for years, certain diseases such as nematodes

TABLE 1

MINERAL NUTRIENTS REMOVED FROM SOIL BY SUGAR BEETS, POTATOES, AND BARLEY

Crop	Yield to the acre	Mineral nutrients removed by the crop		
		Nitrogen	Potash	Phosphoric acid
	pounds	*pounds*	*pounds*	*pounds*
Sugar beets	20,000	30.0	70.0	14.0
Potatoes	12,000	47.0	76.5	21.5
Barley	1,800	48.0	35.7	20.7

and root rot may appear, or the beets may become unhealthy as a result of insufficient mineral nutrients. In these cases there is no poisoning of the land but simply the natural result of growing any crop continuously for years.

This circular cannot outline the particular rotation practices suited to each section of the state. The farmer is urged, however, to plan a cropping system that will maintain a high productivity of his land. In such a system a root crop, such as the sugar beet, will find an important place.

In planning to use beets thus, one should consider somewhat the order and frequency of the crops. Sorghum crops, for example, seriously reduce the yield of a succeeding sugar-beet crop. Yields of beets following cauliflower are also often unsatisfactory. In many instances, too, an inferior beet crop is secured on land that has been in barley for several years. The explanation is probably the plow sole and poor subsoil conditions that have resulted from shallow plowing over a long period. In southern California, beets after barley have been successful provided the barley land is especially prepared by an early-summer shallow plowing, followed by an irrigation that stimulates a growth of volunteer barley and then by a deep fall plowing.

Growers have found that beets do well after peas, beans, alfalfa, potatoes, lettuce, and tomatoes.

In Ventura County the American Crystal Sugar Company has had striking increases in yields of sugar beets and beans with the addition of the annual clover, *Melilotus indica,* as a covercrop in their sugar-beet and bean rotations. Inasmuch as this rotation practice has been productive of such good results, and merits application in other sections, it is described in considerable detail. The rotation system used in that area has been one of sugar beets and beans grown alternately for a number of years. Since 1927, *Melilotus indica* has been added to the rotation, being planted after the beet harvest. The crop residue in form of tops from the preceding beet crop is either disked under when the soil is

TABLE 2

ACREAGE, AVERAGE YIELD OF ROOTS, AND PERCENTAGE AND YIELD OF SUCROSE, BY DISTRICTS, 1933

District or company	Harvested area	Yield of roots per acre	Sucrose percentage	Yield of sucrose per acre
	acres	*tons*	*per cent*	*pounds*
Oxnard: Ocean View	4,244	10.58	20.55	4,348
Oxnard: Pleasant Valley	4,962	12.57	21.50	5,406
Oxnard: A. B. S. Ranches	1,900	10.96	20.48	4,490
San Fernando Valley	1,403	13.65	18.19	4,966
Lompoc	1,991	19.29	19.29	7,442
Santa Maria	1,950	14.07	18.46	5,194
San Luis Obispo	1,039	15.49	19.86	6,152
Union Sugar Co.	217	4.76	19.68	1,874
Chino Ranch	644	12.34	18.48	4,560
Chino	822	15.02	15.66	4,704
Compton	642	15.23	16.86	5,136
Peatlands	1,055	19.71	16.74	6,598
Spreckels Ranch 1	912	24.82	18.06	8,960
Soledad Ranch 2	230	15.99	19.81	6,339
King City Ranch 3	1,415	12.80	19.95	5,108
Santa Clara	346	15.10	19.50	5,891
Pajaro	261	19.69	19.63	7,732
San Benito	1,281	14.53	20.13	5,852
Salinas Valley: No. 1	1,236	18.92	19.36	7,325
Salinas Valley: No. 2	4,561	21.09	19.87	8,386
Salinas Valley: No. 3	2,927	16.18	19.70	6,382
Salinas Valley: No. 4	5,037	16.93	20.01	6,778
Manteca	1,406	6.15	20.30	2,497
Meridian	895	7.58	20.50	3,108
Grimes	1,936	11.10	17.26	3,832
Marcuse	514	11.04	18.48	4,080
Tehama	687	11.88	16.99	4,037
Island	4,908	15.76	18.04	5,686
Sutter Basin	2,321	13.06	17.81	4,652
Sacramento No. 1	11,776	15.77	18.08	5,702
Woodland	10,691	13.84	17.65	4,885
Alvarado	852	14.92	20.22	6,034
Rio Vista	1,505	15.28	18.49	5,650
Stockton	555	21.69	15.99	6,936
Sacramento No. 2	1,379	17.06	19.07	6,506

being prepared for the planting of the clover, or is fed to sheep or cattle. The *Melilotus* is allowed to grow during the winter months. It reaches an average height of 12 to 14 inches by March, when it is plowed under. An immediate irrigation follows, and the soil is thoroughly disked in order to compact it and thus to promote rapid disintegration of the material. By May, when the beans are planted, the clover has disintegrated so as not to interfere with seeding. After the bean harvest, the bean straw is spread over the field and plowed under before planting the following beet crop, which usually takes place in January or February.

The average yield of beans before the green manure was planted, for a six-year period, was 13.3 sacks (100 pounds each) per acre; of beets 10.7 tons. The average yield of beans after including the green manure was 19.5 sacks; that of beets 15.9 tons. An average yearly increase of approximately 6 sacks of beans and 5 tons of beets to the acre has been made, therefore, as a result of an intervening covercrop.

YIELDS OF SUGAR BEETS IN CALIFORNIA

Table 2 shows the average yield of sugar beets in the various districts of California for the year 1933. The figures have been furnished by the various sugar companies operating in California. The "districts" are those designated by the sugar companies.

The performance of a district will vary from year to year with seasonal weather conditions, prevalence of disease, and the like. In every district certain growers produce exceptional crops of beets because of superior farming methods and productive soils. Cases selected from different districts of California show what can be accomplished on good land by a capable farmer (table 3).

PREPARING THE SEED BED FOR SUGAR BEETS

Under average seasonal and soil conditions the different operations in fitting a seed bed for sugar beets are performed in the following order: (1) disking, (2) leveling or floating, (3) plowing, (4) harrowing or disking.

In general, disking before plowing is advisable. The disk cuts up cloddy or trashy soil and provides a surface mulch to be plowed under. Thus there is turned down against the bottom of the furrow a fine soil that forms a close contact with the undisturbed subsoil. If plowing is not preceded by disking, there is danger of turning under clods that may not break up in subsequent operations. As a result, air pockets are formed, so that many roots do not come into close contact with soil particles, and the feeding surface of the plant is reduced.

Leveling or floating should be done in the fall when the soil is abso-

TABLE 3

ACREAGE, AVERAGE YIELD OF ROOTS, AND PERCENTAGE AND YIELD OF SUCROSE OBTAINED BY CERTAIN SUCCESSFUL GROWERS, 1933

District	Harvested area	Yield of roots per acre	Sucrose percentage	Yield of sucrose per acre
	acres	*tons*	*per cent*	*pounds*
Santa Clara	80	16.27	20.10	6,543
Pajaro	40	25.58	18.42	9,427
San Benito	27	28.30	19.62	11,108
Salinas No. 1	55	30.24	19.49	11,792
Salinas No. 2	150	37.57	19.91	14,963
	25	30.65	21.12	12,951
Salinas No. 3	14	40.12	18.63	14,950
	20	33.87	18.92	12,819
Salinas No. 4	35	30.79	18.88	11,630
Marcuse	16	23.44	17.70	8,298
	67	18.64	18.33	6,833
Isleton	325	19.62	16.97	6,659
	100	19.91	18.25	7,267
Liberty Island	50	20.15	21.31	8,588
	155	16.30	22.25	7,253
Walnut Grove	275	19.63	17.78	6,980
Sutter Basin	207	23.26	15.21	7,076
Argenta	100	22.27	18.17	8,093
	40	25.59	18.48	9,458
	100	27.06	18.75	10,147
Del Paso	50	23.86	18.13	8,652
Lovdal	30	25.87	17.57	9,091
	380	20.04	19.40	7,776
Swingle	244	23.19	15.53	7,201
	38	22.46	16.32	7,331
Knights Landing	85	27.14	14.61	7,930
Laugenour	235	26.76	14.46	7,739
Yolo	40	28.05	16.39	9,195
	76	24.73	16.56	8,191
	29	31.52	16.71	10,534
Alvarado	15	35.16	17.82	12,532
	100	22.80	21.76	9,922
	5	36.89	21.22	15,656
Ryer	100	30.12	17.24	10,386
Bacon	391	27.02	16.53	8,932
Empire	60	27.88	15.50	8,642
McDonald 4	1,656	28.65	14.23	8,152
McDonald 11	60	32.89	17.07	11,228
Rio Blanco	210	28.97	16.01	9,276
By-pass	240	27.85	20.57	11,458
Greendale	100	27.28	19.01	10,350
Oxnard	185	20.33	19.93	8,104
	60	25.46	18.02	9,176
	75	26.05	19.39	10,102
Lompoc	300	25.11	19.53	9,808
	55	29.03	16.36	9,499
	107	22.51	20.72	9,328
San Luis Obispo	61	26.95	19.11	10,300
Santa Maria	62	26.45	19.35	10,246
San Fernando	52	22.08	18.23	8,050
Chino	60	21.51	15.15	6,517
	38	22.30	15.22	6,788
Compton	28	28.77	14.32	8,239
Elftman	75	20.67	15.36	6,350
Peatlands	19	31.75	15.08	9,576
	28	35.63	16.09	11,482

lutely dry. Very often insufficient leveling is done, with the result that irrigation costs are excessive and the crop is reduced because of damage by flooding.

In most sugar-beet sections of California, fall plowing is strongly recommended, particularly with heavy soils, though there may be certain conditions under which this plan is impracticable. Fall-plowed land retains the winter rainfall and permits seed-bed preparation for early planting. If ridge planting, which is discussed later, is contemplated, fall plowing is usually desirable, for the ridges need to be made in the

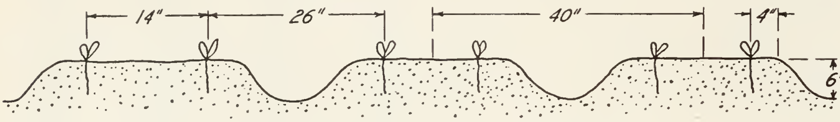

Fig. 2.—Method of ridge or bed planting.

fall. Plowing in preparation for beets should be deep—that is, from 10 to 12 inches. In no case, however, should much raw soil be plowed up.

In most parts of California the plowed soil is left rough during the rainy season. As soon as the land can be worked in late winter, it should be disked or harrowed, according to soil-surface conditions. Harrowing, generally the last operation before seeding, should be thorough. Two harrowings, the second at an angle to the direction of seeding, are advisable. The harrow teeth should run at a slant so that there is some packing and leveling of the surface soil.

When beets follow alfalfa, the alfalfa should be crowned by shallow plowing, 2 to 3 inches deep, as early during the late summer as possible; and a deep plowing should follow several weeks later. This early crowning during warm weather is necessary in order to bring about the killing of the alfalfa and a maximum amount of decomposition. If alfalfa land is prepared late, when rainfall occurs, there may be much volunteer growth, and proper seed-bed preparation is seriously interfered with. Furthermore, this regrowth and undecomposed trash may result in loss of stand during the cultivation of beets.

A seed bed for beets should be *firm*. All too often not enough work is done in seed-bed preparation.

RIDGE PLANTING OF SUGAR BEETS

In most sugar-beet districts of this country and Europe, flat planting is the usual method. Within the last few years the planting of sugar beets on ridges or beds has attracted the attention of sugar-beet growers in various parts of California. This method is familiar to growers of lettuce and certain other vegetables. In the Salinas Valley, for several years,

Fig. 3—Ridge planting. The ridges are formed by a lister.

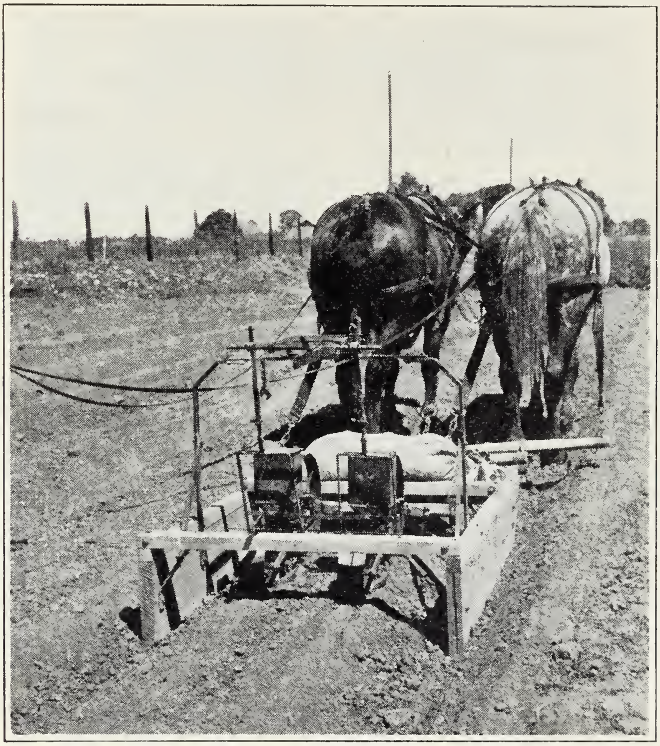

Fig. 4.—A single-bed homemade ridge planter.

most of the sugar beets have been planted on beds. The results have been satisfactory, farmers showing no inclination to return to the old method of flat planting. In other parts of the state, north, central, and south, the results of ridge planting have been almost wholly satisfactory. Apparently this method is peculiarly adapted to the California soil and climatic conditions, and to irrigated agriculture; and it will probably gain in favor generally throughout the state. Any beet grower should give it a fair trial, in comparison with flat planting.

The ridge planting of sugar beets, as practiced in the Salinas Valley, will be described here. The ridges are prepared so that the centers are 40 inches apart (fig. 2). The ridges are formed by a lister (fig. 3). Since two rows of beets 14 inches apart are planted on each ridge, a distance of 26 inches is left between the rows of two adjacent ridges. This spacing permits the same number of beets per acre as when the beets are planted in evenly spaced rows 20 inches apart.

It is advisable to construct the ridges in their rough form—more or less an inverted V-shape—in the fall. Thus, the soil in the beds has opportunity to settle during the rainy season. Apparently this is important. In case the ridges cannot be formed dry in the fall—that is, if ridging is done in late spring and is followed immediately by planting—the ridges must be packed well before planting. The shaping of ridges is accomplished with a sled equipment, the runners of which run in furrows (fig. 4).

Seeders should usually be attached to the ridge shaper so that shaping of the ridges and seeding can be done in one operation. Various types of ridge shapers and seeders are in use, most of which have been constructed in local shops. Some types shape and plant one ridge at a time, others are equipped for two ridges, and others will shape three ridges (figs. 5 and 6) at one time.

Ridges should be broad enough so that the rows of beets do not come too close to the shoulder of the ridge. A distance of 4 to 5 inches should be between the edge of the row and the ridge shoulder.

Cultivation is done with the usual cultivating implements, except for the knives which run along the slopes of the ridges. These, known as crescent knives, are curved to conform to the shape of the ridge. In cultivating, furrowing-out shovels should be attached to the tool bar and so set as to throw the soil back against the ridges, and thus keep them in shape and prevent their drying. In certain sections, where the beet-lifting plows are adapted to only one row, beets have been successfully grown on ridges, planting one row to a ridge, with the ridges 20 inches apart.

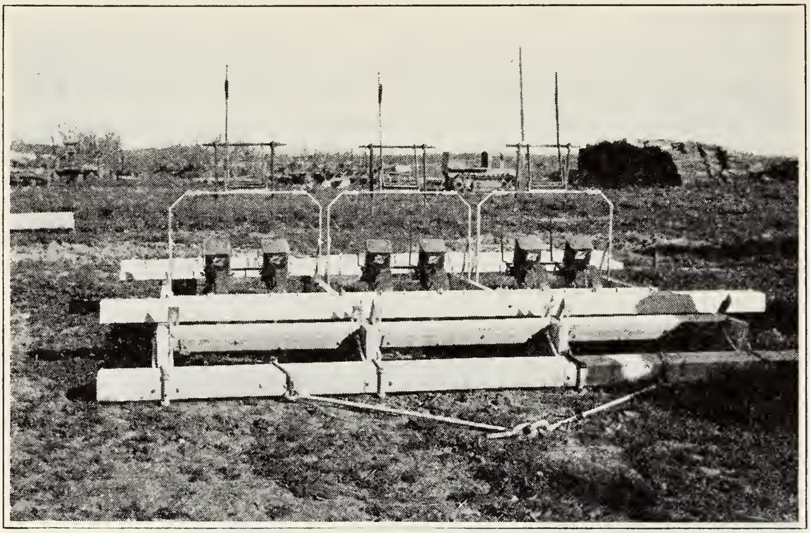

Fig. 5.—A three-bed ridge planter, which shapes and plants the beds after listing, equipped with seeders.

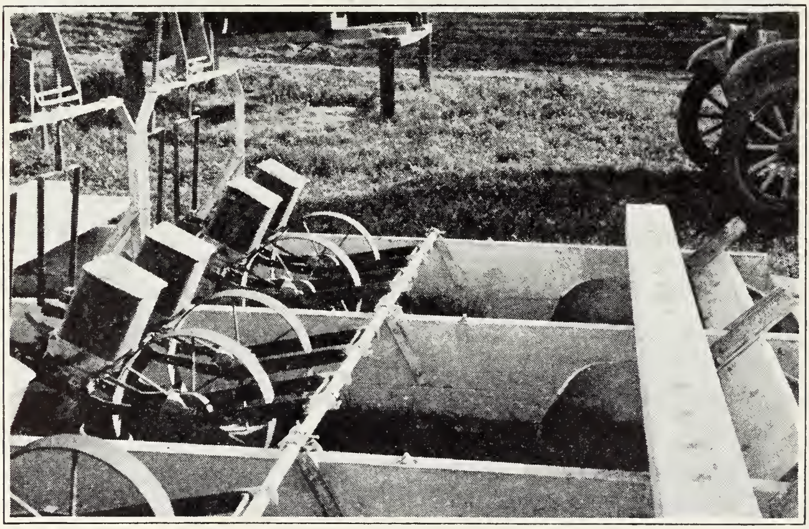

Fig. 6.—Close view of three-bed ridge planter. The slanting board on the front is adjustable up and down for leveling off the top of bed. Note the boiler-plate wings for shaping the sides of the bed.

As compared with ordinary flat planting, ridge planting has several advantages:

1. It is peculiarly adapted to an irrigated type of beet culture in that (*a*) it permits the irrigation which in cases may be necessary to cause seed germination, (*b*) it distributes water in deep furrows so that none stands about the crowns of beets, and (*c*) it eliminates the danger of covering young beets in furrowing out.

2. It is especially adapted to beet culture where seeding is done early and is followed by wet and cold weather, in that (*a*) seeds on ridges

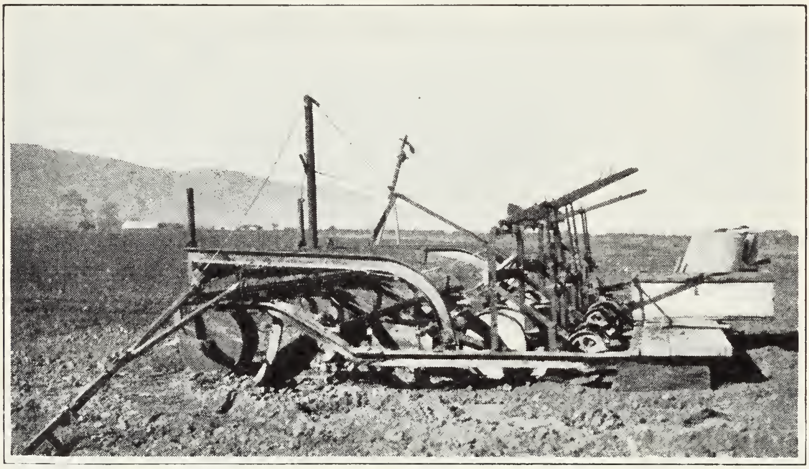

Fig. 7.—Combination lister and planter. This makes the seed beds, smooths them off, and plants, all at one operation.

germinate earlier, which permits early thinning, cultivation, and irrigation, (*b*) the young plants receive good aeration and drainage, and (*c*) there is less tendency to crust formation.

3. In lifting two rows of beets 14 inches apart, there is efficient performance on the part of the lifting plow, on which shorter wings may be used, cutting down the draft necessary.

4. The cost of ridging is not high and according to experienced farmers is more than offset by the increased yields of beets on ridges as compared with those planted flat.

It should be remembered that irrigated territories have adopted the traditional methods of beet culture of countries that do not practice irrigation. Although changes are often made reluctantly, ridge planting of sugar beets is worthy of a thorough trial in view of its great success in many sugar-beet-growing sections in California.

SEEDING

Sugar-Beet Varieties.—From the beginning of the sugar-beet industry in the United States, this country has secured practically all its sugar-beet seed from Europe. During the World War, however, much seed with a high percentage of germination and capable of developing satisfactory beets was grown in this country. Soon after the War, however, chiefly because of the relatively high cost of producing seed in the United States by the conventional two-year method, involving the production of stecklings the first year and seed therefrom the second year, this country again became dependent almost wholly upon the European supply.

Within the last few years the United States Department of Agriculture has developed the overwintering-in-the-field method, in which the seed is produced within one year and production costs thereby greatly reduced. The federal government and some beet-sugar companies have again become actively concerned with beet-seed growing, chiefly through the necessity of producing seed increases of strains resistant to certain diseases. This country is now well on the way toward developing a domestic sugar-beet-seed industry; at present (1935) almost 2,000 acres of seed are being produced. The cost does not exceed that of European seed. A still more important consideration is that domestic seed production will foster the use of sugar-beet varieties developed in the United States having marked resistance to specific diseases and adaptation to specific conditions.

At present some forty or fifty brands of sugar beets are used for commercial beet production. The brands commonly used in California are shown in the following list, which also indicates the country in which the seed is produced.

Czechoslovakia: Dobrovice and Wohanka
Denmark: Hartman (Glostrup) and Erhard Fredrickson (Eagle Hill)
England: Johnson & Co. (Perfection Non-bolting)
Germany: R & G Normal, R & G Old Type, Strube, Terra, Braune, Schreiber's S. S., Dippe–GDWI, Delitsch
Holland: Kuhn
Poland: Janasz No. 1, Janasz No. 2, Udycz, Busczynski
United States: U. S. No. 1 (Curly-top Resistant)

Variety field tests indicate in general that beet varieties differ in several respects: Yield of roots, percentage of sucrose, purity, resistance to specific diseases, tendency to bolt (that is, go to seed the first year), ripening, and other responses to soil and climatic conditions. No one variety will give the best results under all conditions or in all areas. This means that more attention should be given to selecting varieties adapted to different sugar-beet districts.

The larger breeders and producers of sugar-beet seed in Europe usually have at least two principal strains, a "yield strain" and a "sugar strain." The former is the slower in maturing and produces a higher tonnage but a lower percentage of sucrose.

The variety tests made thus far in most districts of California have usually been inadequate, so that a particular grower can seldom predict which variety or varieties will give him maximum returns.

In most beet districts of California, except the Delta region, "yield strains" give greater returns than "sugar strains." In the Delta, where the richness of the soil in nitrates postpones maturity and encourages high tonnage, "sugar strains" may give superior returns. Growers with large acreages will do well to conduct a limited test of varieties on their own land.

The Drill.—Poor stands are often traceable to improper drill performance. Proper drill adjustment is easily accomplished by the grower; yet often this important operation receives very little attention. Many drills do not deliver sufficient seed or are not adjusted for proper depth of planting; or, if shoe drills are used, the shoes are not sharp, and consequently the seed is not placed in the bottom of the furrow made by the shoe. The beet drill should be tested and adjusted before planting.

Drills are calibrated when they leave the factory for different rates of seeding. This calibration is usually found either on a card in the drill box or in a book of instructions covering the adjustment of the drill. The factory calibration of the drill is for average-sized seed. Since seed varies in size, a drill will not deliver so much per acre if the seed is large as if it is small. The drill should therefore be calibrated for the size of seed used that particular season.

A simple test for rate of seeding can be accomplished as follows: The drill should be jacked up so that the wheels clear the ground, and the tongue propped up so that the drill sets level. Rows are, on the average, planted 20 inches apart, in which case 26,136 feet of row are required for an acre. To expedite testing of the drill, turn the drill wheel enough times to cover $\frac{1}{10}$ acre, or approximately 2,613 feet of row. Since four rows are being seeded if a four-row drill is used, 653 feet must be traveled by the drill for $\frac{1}{10}$ acre area. If the wheel is 10 feet in circumference, it must be revolved $\frac{653}{10}$, or 65.3 times to cover $\frac{1}{10}$ acre area. Pans placed under each shoe catch the seed for weighing and the uniformity of drilling for each shoe is determined. Ten times the total weight of seed caught in the pans will be the amount of seed the drill is planting per acre. If this total is 2 pounds, the drill is planting 20 pounds per acre, which, under ordinary conditions, should be the minimum amount.

The depth of planting is also very important. The best depth will vary with the season. Winter planting is usually shallow; spring planting somewhat deeper. One should seldom plant over 1½ inches deep. To adjust a shoe drill for depth of seeding, place the wheels on a firm

TABLE 4

TIME-OF-PLANTING TESTS, DAVIS, CALIFORNIA; AVERAGE OF FOUR YEARS*

Date of planting	Number of beets harvested per 100 feet of row	Percentage of bolters	Average weight per beet	Sucrose percentage	Yield of roots per acre	Yield of sucrose per acre†
		per cent	*pounds*	*per cent*	*tons*	*pounds*
November	79	43.5	2.5	15.6	25.0	7,793
December	81	26.2	2.5	16.3	25.7	8,403
January	100	1.5	2.3	17.3	30.7	10,601
February	103	0.0	2.0	17.2	26.6	9,175
March	102	0.0	1.6	16.6	21.1	6,988
April‡	92	0.0	1.2	17.4	14.2	4,919

* From: Esau, Katherine. Planting season for sugar beets in central California. California Agr. Exp. Sta. Bul. **526**:5. Table 1. 1932.

† Averages of the yields for the individual years, and therefore differing slightly from the product of the means given in the table.

‡ Average of two years.

board that will raise them to a distance equal to the depth you wish to plant. If this depth is 1 inch, use a 1-inch plank. Adjust all shoes so as to come down even with the floor or ground when the tension lever is brought backward, that is, when the shoes are in their lower position. In adjusting the drill, prop the tongue up so that the drill sets level. With a disk planter one need only set the bands to the desired depth on the disks.

Time of Seeding.—The sugar beet normally requires a long growing period. In general, consequently, early seeding is advisable. In most California beet territories there has been developed within the last few years a tendency to plant earlier than formerly. Early planting has brought somewhat better yields and has enabled the grower in districts attacked by the leafhopper to reduce the serious injury that often follows late seeding. Temperatures will permit seeding during any month from November to April in any sugar-beet district of the state. Fully 90 per cent of the seeding in California is done before February 15.

Time-of-planting tests were conducted in central California during four consecutive seasons, 1927–1931, upon a typical Yolo loam soil, at Davis. Seed was planted every month from November to March. During two years the plantings were extended until April, and once a planting was made in October. The average results for the four years, shown in table 4, indicate the superiority of the January and February plantings.

Beets seeded early often have a tendency to bolt. This is also shown in table 4. The earlier the planting, the greater the percentage of bolters. In general, the later the bolters appear, the less is their effect upon size

TABLE 5

Bolters Compared with Normal Beets*

Date planted	Date harvested	Bolters			Normal beets		
		Number of beets in sample	Weight per beet, pounds	Sucrose percentage	Number of beets in sample	Weight per beet, pounds	Sucrose percentage
Davis, Yolo County							
Nov. 11, 1930	Aug. 31, 1931	5	2.3	16.1	5	1.6	16.6
		4	2.1	18.6	4	2.4	16.6
		4	2.6	16.9	4	1.8	17.2
		3	2.4	15.4	3	2.5	16.7
		4	3.1	16.6	4	3.4	16.5
		Average	2.5	16.7	..	2.3	16.7
Staten Island, Sacramento County							
Jan. 18, 1930	Aug. 29, 1931	9	1.4	15.5	10	1.5	14.6
		10	1.2	17.4	9	2.0	17.3
		10	1.9	15.7	10	0.8	17.2
		10	1.5	15.1	10	1.9	15.2
		10	2.5	17.4	10	1.6	17.0
		10	2.2	14.7	10	1.2	17.0
		Average	1.8	16.0	..	1.5	16.3
Jan. 18, 1930	Aug. 31, 1931	15	2.1	14.6	15	1.6	14.7

* From: Esau, Katherine. Planting season for sugar beets in central California. California Agr. Exp. Sta. Bul. **526**:17. Table 5. 1932.

and quality of the root. Considering all the California beet territory, however, the yield and percentage of sugar are often not materially affected by bolting. This point is emphasized in table 5.

Certain strains have a stronger tendency to bolt than others. The grower who contemplates early seeding should ask the sugar company for seed of a strain that shows this tendency to a relatively slight degree.

As concerns central California specifically, and also most other sections of the state, the following conclusions as to time of seeding, taken from Bulletin 526, may be given:

Early planting of sugar beets is recommended for central California in preference to late spring plantings. By early plantings are meant those beginning about the middle of November and completed not later than the end of February.

Late plantings have the following disadvantages: The plants have a short growing season and do not attain so large a size as early-planted beets. It is frequently difficult to obtain good stands in spring and early summer because of lack of moisture, dry winds, and high temperatures. Late-planted beets in years of outbreaks of curly top are exposed to a very severe infection.

Early-planted beets, on the other hand, have a long growing season. Since they are comparatively large when climatic conditions permit the most rapid growth (spring and early summer), they take the fullest advantage of these conditions, and their rate of increase at this time is higher than that of the still small late-planted beets.

The early plantings get the benefit of the winter rains to a higher degree than late plantings; and the beets make the major part of their growth during cool weather, which is beneficial to the development of the plant.

Beets planted early have attained considerable size at the time they are [liable to be] infected with curly top; hence they are relatively resistant to this disease, and the damage . . . is materially reduced.

When beets are planted early, more time is available for reseeding in the case of stand failures.

Considering the late fall (November–December) and winter (January–February) plantings separately, experience has shown that January and February are generally more favorable months for planting sugar-beet seed than November and early December. [In certain districts of the Salinas Valley, November and December plantings may be advisable.] A number of difficulties may be encountered in late fall plantings.

It is frequently difficult to obtain good stands in late fall. The seed germinates slowly in the cold ground, and if a crust is formed the seedlings have [little] power to penetrate to the light. Or, on the other hand, heavy rains may drown out the slowly growing young plants. Stands may also be materially reduced by damping-off, especially in heavy soils with poor drainage. Frost may injure the plants that are just emerging above the surface of the ground.[3]

November and December plantings produce bolters, and this feature may in some years become seriously objectionable. Bolters frequently yield woody fibrous roots, and the seed stalks cause difficulties during harvest. The yield and percentage of sugar are apparently not materially affected by bolting under California conditions if the percentage of bolters is not extremely high and the seed stalks do not appear too early.

The period between early January and the end of February, on the other hand, is usually very favorable for planting because at that time the temperature rises, the soil becomes warmer, the seed germinates rapidly, and the plants grow fast, give good yield of roots and sugar, and produce few or no bolters. The January and February plantings frequently give more sugar to the acre than the November and December plantings because of the higher percentage of sugar combined with good yield of roots.

In conclusion: Late December, January, and early February are recommended as particularly favorable months for planting sugar beets in central California (San Joaquin, Sacramento, San Juan, and certain parts of the Salinas valleys).

[3] Esau, Katherine. Planting season for sugar beets in central California. California Agr. Exp. Sta. Bul. 526:1–20. 1932.

Rate of Seeding.—A good germination stand is so essential that skimping on seed is unwise. The seed constitutes, moreover, a very small proportion of the total cost of a crop. With the most favorable soil and weather conditions a satisfactory germination stand may infrequently be secured with 10 to 12 pounds of seed to the acre. But one can never determine at seeding time what conditions may arise to decrease the percentage of germination or weaken and destroy the seedlings. A beet sprout exerts considerable force in pushing its way to the surface of the soil; hence heavier rate of seeding has the advantage of providing a greater lifting force that may be significant in a soil inclined to crust. Generally speaking, it is unwise to plant less than 20 pounds of seed to the acre.

Width of Rows.—This topic is discussed in part under the heading of "Spacing Beets, and the Influence of Stand on Yield" (p. 31). In most California sugar-beet sections where flat planting is practiced the rows are 20 inches apart. This spacing gives ample room between the rows to form the furrows for irrigation.

A very satisfactory spacing of rows in irrigated districts practicing flat planting is one with a "14 and 26" inch spacing. This "14 and 26" spacing has several distinct advantages: (1) In the 26-inch space there is abundant room for a deep, wide furrow, made while the beets are still young without danger of covering them with soil. (2) Because of the possibility of early furrowing-out, the first irrigation may be applied earlier than is usual. (3) The irrigation furrows being only in the 26-inch spaces, there are one-half as many furrows to the acre as with the usual method, and the labor cost of irrigation is thus reduced. The common error where this type of spacing is used is that the grower spreads the irrigation water over the field and allows it to run the same period of time as he formerly did when every row was irrigated; thus approximately half as much water is applied as originally. In many cases insufficient water is given at each application for maximum returns. (4) The last cultivation may be done when the beets are of good size without danger of injuring the plants, because the tractor wheels or horses occupy the 26-inch space.

The disadvantage of this "14 and 26" spacing of rows is that in very heavy soils even distribution of water to all beets may not be secured where every other row is irrigated. There is not the uniform distribution of individual beets that is obtained when the spacing between rows is the same throughout the field. Again it is well to emphasize that uniformity of stand, in which each beet has the same soil volume in which to develop, is important in securing high yields of both roots and sugar.

THE DEVELOPMENT OF THE BEET PLANT THROUGHOUT THE SEASON

From the time of seeding to harvest, changes in the form and chemical constitution of the beet plant, both top and root, take place. A knowledge of these changes is a guide to cultural practices.

Each beet ball or so-called "seed" has one to five true seeds. Each true seed contains a young plant (germ, or embryo) surrounded by reserve food. During germination the root is the first structure to emerge from the seed (fig. 8). The root lengthens, develops a few slender side roots, and grows rapidly downward. This root becomes the beet at harvest. Later the cotyledons, or first leaves, emerge from the seed and are brought upward to the soil surface. During these early stages all nourishment is derived from the reserve food in the seed; this reserve is outside of the embryo itself, but is used by it in its early growth. Once the cotyledons are in the light, they become green and begin manufacturing food. The young plant is then independent of the stored food in the seed.

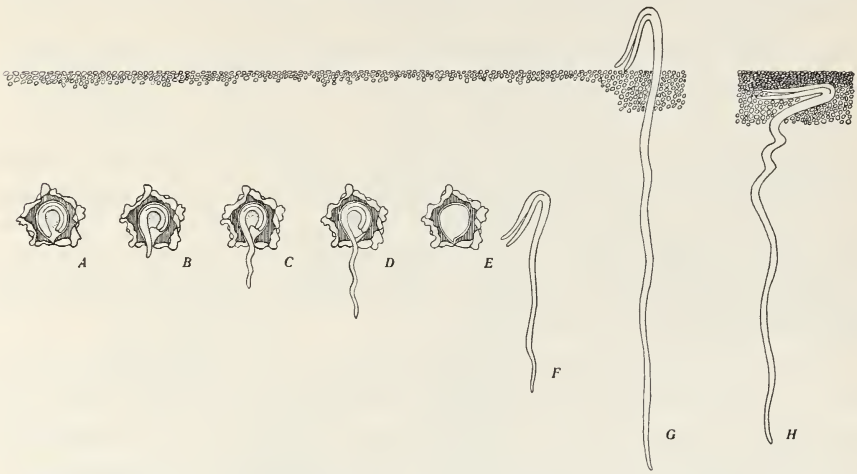

Fig. 8.—Stages in the germination of a beet seed. The curved embryo or germ is enclosed by a corky material and surrounds a reserve food supply (shown dotted). In stage *F*, the young plant is no longer in contact with this food supply. The critical stage in the life of the seedling is that between *F* and *G*. Note the effect of crust in stage *H*.

The critical period for the seedling is the interval between the time when the seed leaves become freed from their source of food supply and the time when they emerge into the light. During this period the young plant is growing and working entirely upon such little food material as may be stored within its own body. All new growth made weakens it rather than strengthens it. The seed leaves must come quickly into the light, for only with the aid of light can they make food to add to the strength of the seedling.

Under favorable conditions the seed leaves emerge on the soil surface about two days after pulling away from the starchy food supply. Under unfavorable conditions this period will be lengthened. If seed is sown too deeply, if a crust prevents the sprouts from reaching the light, if adverse soil temperature, soil moisture, and clods retard growth, then the reserve of the young plant may become exhausted. In a weakened condition the plant is easily attacked by soil fungi, which cause root-rot.

According to microchemical tests made just after the young plant appears above the ground, it contains very small quantities of sugar, starch, fat, and protein—the different foods necessary for growth. But once in the light the seed leaves make food rapidly, the young plant gains strength, produces new leaves, and thus finishes a critical period in its early life.

The germ must have adequate water, air (oxygen), and heat in order to germinate. Of course, if the soil is too dry, the seed does not germinate on account of a scarcity of water; and if the soil is saturated, oxygen is partially excluded. The minimum temperature at which beet seed germinates is about 35° Fahrenheit, the maximum from 83° to 86°, and the best temperature about 77°.

Following the cotyledons, or seed leaves, is the first pair of true leaves; then the second pair develops. When the buds of the latter are appearing, an outer coat of the root begins to slough off. The brownish shreds attached to the young root at this stage have an unhealthy appearance that may easily be mistaken for "black root."

When the plant has been from 7 to 10 days above ground, the root has reached a depth of 6 to 10 inches. At thinning time it may have reached 12 to 18 inches. Throughout the season the main root grows steadily downward, sending off lateral roots in all directions. At harvest the roots may attain a depth of 6 feet, provided there is not a high water table or plow sole, and a lateral spread of 3 feet. Where a plow sole has been formed because of continued shallow plowing, short, sprangling roots often develop. If there is a plow sole, deep plowing or subsoiling before planting is advantageous in breaking it up and allowing deep penetration of the taproot. Towards the middle of the growing season, the weight of root exceeds that of top. The root gains weight until harvest, whereas the top loses weight because of the death and loss of the outermost and oldest leaves.

Not all leaves of the plant are equally active in manufacturing sugar. The outer and older leaves are less active than the younger ones that occupy a position near the center of the crown. Consequently, the removal or injury of old leaves will harm the plant relatively less than the removal or injury of younger leaves. Experiments show, however, that damage to any live leaves is detrimental to yield and sucrose percentage. These facts emphasize the need of care in cultivating beets and in preparing ditches so that as few leaves as possible are injured. Ditch-

Fig. 9.—Ideal type of sugar beet.

ing or cultivating when tops are large should be performed during the middle of the day when the leaves are wilted and do not bruise or break off easily. A late loss of leaves through any cause reduces the percentage of sucrose in the beet relatively more than it does the tonnage, whereas an early defoliation is particularly effective in reducing yield of roots.

Because sugar is made in the leaves and transported from them and stored in the root, some have concluded that the more leaves a plant has, the greater must be the sugar production. Actual results do not support this conclusion. Individual beet plants apparently differ in their growth materials. As certain tests showed, for example, the total fresh weight (roots plus tops) of one acre of beets was 24.96 tons; that of another acre approximately the same, 24.92 tons. But the first acre yielded 17.37 tons of roots or 69.64 per cent of the total growth; the second, only 13.7 tons of roots or 54.97 per cent of the total growth. The ratio of roots to tops varies markedly and is modified by many different conditions. Manure and commercial nitrogenous fertilizers increase the percentage of tops. In an impoverished soil the ratio of roots to tops is high. According to the data, a high percentage of roots or of tops is not necessarily correlated with a high yield of roots or with a high percentage of sucrose.

What is the ideal type of sugar-beet root? What external characters mark an excellent root? Since the very beginning of developing sugar-beet strains, the breeder has had certain ideals. Tonnage, sucrose percentage, and purity have, of course, been the chief objectives.

Root shape is a heritable quality. Figure 9 illustrates what is regarded as a very desirable type of beet root. Note the small crown and the long tapering form of the root with the weight carried well down below the middle. A superior beet should be free of "sprangles," of excess side roots, and of deep grooves, because these hold dirt and add greatly to the tare. Well-shaped beets are more likely to develop if grown carefully under proper conditions than if grown carelessly under unfavorable conditions.

The ideal beet field has a perfect stand, in which the beets are regularly spaced and uniform in size and shape. Lack of such uniformity at harvest indicates differences throughout the field in soil quality, distribution of water, spacing, and cultural care given. In most commercial fields enormous beets may occur alongside beets of small or medium size. The unusually large beets frequently have a very large and hollow crown, an inferior shape, a low percentage of sucrose, and low purity. The beet grower should not strive so much for large roots as for well-shaped roots, medium and uniform in size, and perfectly distributed. Not only is the yield, as regards tonnage, percentage of sucrose, and purity, of such beets greater than that of beets lacking these characters, but also the costs of harvesting are less.

CULTIVATION OF SUGAR BEETS

Preparation of the soil before planting sugar beets will greatly influence the success of obtaining a satisfactory stand, and the nature and need of subsequent cultivation. An earlier section of this circular has dealt with methods of seed-bed preparation (p. 8). Cultivation after planting

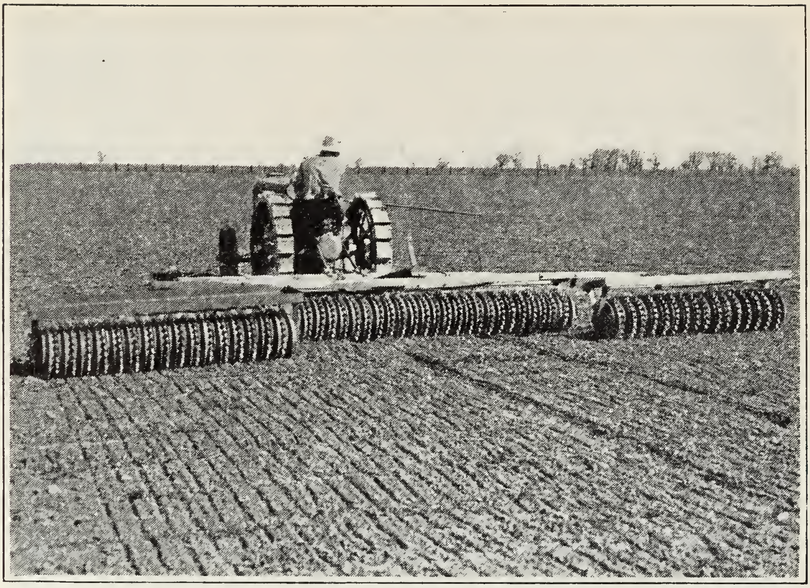

Fig. 10.—Corrugated roller used as a crust breaker and also after the first cultivation in preparation for blocking and thinning.

Fig. 11.—Harrow mounted on sulky used to break crust on ridges.

will be influenced largely by the type of culture used. Two general types of beet culture prevail in California: one in which the beets are planted on ridges or beds, and one in which they are planted flat. Tools must be adapted to the type of culture and must be adjusted on the cultivator to conform to the width of row.

Crust Breaking.—In certain soil types the formation of a crust often explains failure to secure a germination stand. Crust is likely to occur

Fig. 12.—The portion of the field in the left half of the photograph was rolled and left uncultivated. The portion of the field on the right was cultivated with disks and duckfeet before a heavy wind storm. The rolled portion of the field was replanted, shortly after the photograph was taken, because of the damage to the seedlings by the wind.

in adobe and clay soils, as well as in other types deficient in organic matter. Figure 8 *H* (p. 21) shows in diagram the behavior of beet seedlings in a crusted soil. It has been pointed out that during the early stages of beet-seed germination, when the young plant makes its growth wholly at the expense of a reserve food supply in the seed, the germ is in contact with this supply. After a time the reserve is exhausted, and the young plant is left "on its own." Unless it promptly reaches the light, where it can manufacture its own food by using substances absorbed from the soil and air, it dies or is so weakened as to fall an easy prey to soil fungi. Crust, consequently, must be prevented or quickly broken, to allow the seedlings to come into the light.

The tendency to crust formation may be lessened by incorporation in the soil of barnyard manure or of organic matter furnished by plowing under a covercrop. Crust prevention is one thing, crust breaking another. On certain soil types, crust forms very rapidly after a rain, particularly if warm weather and dry winds ensue. In this event, the time when soil conditions permit working is extremely short, and crust prevention may be almost impossible. In this case, crust breaking must be resorted to. There are various types of crust breakers, chief of which is the corrugated roller (fig. 10). A danger in using any type of heavy roller is that of compacting the soil.

A few implements employed in crust breaking are: (1) roller (*a*) corrugated (fig. 10) or (*b*) flat; (2) harrow, (*a*) spike-toothed or (*b*) specially designed with spike nails or (*c*) harrow mounted on a sulky, designed to break crust on ridges (fig. 11); (3) knives or disks, followed by the roller for blind cultivation; (4) rotary hoe. The implement selected should be one that most effectively does the job in the particular field in which it is used.

In very light sandy soil, the surface is left smooth by the corrugated roller; and this smooth surface when exposed to strong winds, in certain sugar-beet areas, tends to shift about, injuring the seedlings. Wind damage is shown very strikingly in figure 12.

A flat roller, though sometimes used for breaking crust, is seldom as effective as the corrugated roller.

The spike-tooth harrow is sometimes useful. To operate it in the same direction as the row is frequently objectionable because trash may hang up on the harrow teeth; and if one of the teeth runs too deeply, part or all of the seedlings in a drill row will be dragged out. One should therefore harrow either at right angles or in a diagonal direction to the row.

A small harrow has been designed to break crust on small acreages. It consists of two timbers (4 × 4 inch) for runners with two cross pieces (2×10 inch). Large spike nails are driven through the 2×10 inch planks so that when the harrow is run over the soil all the area between the runners is covered by the spikes. The spikes can be driven in or pulled out of the planks to suit the depth required for breaking the crust effectively. This implement has an advantage over an ordinary spike-tooth harrow in that the teeth are smaller. It can be weighted down without digging in too deeply, the runners controlling the depth to which the spikes will penetrate the soil.

This harrow was effectively used on experimental plots planted on ridges. It is mounted on a sulky, and the depth that the teeth penetrate the soil is regulated by a lever. This implement does an excellent job of breaking the crust and leaves the soil in a fine condition.

"Blind Cultivation."—Some growers prefer to break the crust by means of "blind cultivation." This consists in cultivating the rows with

knives or disks before the seedlings come through the soil; then a roller is generally used to break the crust immediately over the row. This system is usually employed when the seed has germinated and the seedlings are close to the surface. It requires a skillful operator because the rows are evident only by the press-wheel marks, and if the knives are not properly adjusted a reduction of stand will result without the operator's being conscious of the damage.

Cultivation After Seedlings Appear.—Much has been said about the cultivation of beets before the appearance of the seedlings because of the importance of a good stand. Subsequent cultivations are equally important and should be done at the proper time. The number needed will largely depend upon weed control. A favorable environment should be maintained at all times.

Knives are generally used for the first cultivation, with a duckfoot in the middle of the row. Disks are sometimes employed in trashy soils. The first cultivation should be given as early as it is needed to eliminate the weeds. In weedy fields, it is needed as soon as the beets are visible in the row. Beets should never be forced to compete with weeds, because weeds are a heavy drain on moisture and plant food, generally grow more rapidly than beets, and crowd in a manner detrimental to the normal development of the plant.

Wherever possible, the use of a disk attachment in the first cultivation should be avoided. The disks leave the row of beets on a ridge 1 or 2 inches high and 3 to 6 inches wide. If the disk is used, attach at the same time tools that will throw the soil back against the shoulder of soil, for this shoulder, if left exposed to the wind and sun, dries out very rapidly, so that the young plants are bound to suffer. When the blocker strikes this ridge with his hoe, moreover, he takes not only a block of soil the width of the hoe, but with it often a portion of the ridge on both sides of the hoe, and thus considerably widens the spacing interval between beets. The soil may be pushed back against the ridge by rolling the beets parallel with the rows.

The second cultivation is usually given soon after the blocking and thinning operations are completed. During this cultivation, two things should be kept in mind: (1) weed control and (2) the pulling of the soil as close to the thinned plants as possible without covering them. In adjusting cultivator tools, care should always be used so that young beets are not covered with soil. Covered beets may survive and develop a fair-sized root, but not so large as if they were unhindered in their growth.

The frequency at which following cultivations are given will depend upon the weed growth and the method and time of irrigation. If irrigation is necessary soon after thinning, a chisel placed on the cultivator in the middle of the row will loosen the soil, permitting the irrigation shovel to run sufficiently deep to make a good furrow. All deep cultivations should be given during the early development of the beet because as the season advances there is increasing danger of cutting off the side roots.

Two or three hoeings of sugar beets are usually required. During the first hoeing, doubles if numerous should be removed.

THINNING SUGAR BEETS

One of the most readily controllable operations in growing sugar beets, and one that largely determines the final yield, is thinning. It is one of the most important steps in securing a good stand.

Reasons for Thinning.—The beet "seed ball," as it is known commercially, is a corky structure containing from one to five true seeds. A seed ball containing several seeds arises when the flowers are in clusters; in this case, the parts of the several flowers grow together, forming a several-seeded mass. If a flower stands by itself on the stem, a single-germ beet seed is produced. An ordinary commercial lot of seed contains a relatively small percentage of single-germ seeds.

From one seed ball, one to five plants may grow. These young plants come out of the ground so close together that they necessarily compete for space in which to spread their leaves and roots, and for water and plant nutrients. If some of the plants were not removed, there would be insufficient nutrients in the soil to support their best growth; leaf development would be hindered; roots would be small and twisted about one another; and the returns in tons of roots and sugar per acre would be unprofitable. In thinning, therefore, the object is to leave the largest and healthiest seedlings, distributed evenly in the row so as to permit normal development. Also, in thinning, weeds in the rows and in places which the cultivator cannot reach should be removed.

The Age at Which Beets Should Be Thinned.—According to the general experience of beet growers, the highest tonnage yields are secured by thinning beets when they have attained a stage of development indicated by the presence of two to four *true* leaves. In a seedling of this age there will be, in addition to the two to four true leaves, two seed leaves (cotyledons). Thinning later, when the plants have as many as eight true leaves, may injure the plants that are left. In the first place, by postponement of thinning, the plants have been so crowded as to be retarded in their growth; and second, the root system has attained a growth that is easily disturbed.

In soils infested with wireworms or centipedes, or where damping-off is a factor, blocking with a long-handled hoe, followed by a delay of seven to ten days in thinning the beets to a single plant, is superior to the one-operation method of blocking and thinning to a single plant with a short-handled hoe. In one case an increase in stand of 25 per cent was gained by blocking the beets and leaving the block unthinned for ten days. A 3-inch block was left, and by the time the beets were thinned it was possible to leave in the block a beet that was not injured by the wireworms. If the wireworm infestation is severe, all the beets may be taken; but this practice should receive careful consideration, not only in fields infested with pests but in fields generally. The time that should elapse between blocking and thinning will depend upon the stage the beets have reached. As has been pointed out, beets should be thinned at the 2, 4, or 6-leaf stage, according to weather conditions; but a delay of thinning out to a single plant proves beneficial especially when wireworms or centipedes or damping-off diseases are present.

Generally, the smaller the beets when thinned, the less their growth will be checked. Very early thinning, however, may be followed by a relatively great loss. The reason is that the weakest seedlings often succumb to seedling diseases, the greatest mortality occurring before the plants have developed the second pair of leaves. As there is some natural elimination of the weak plants, time should be allowed for this natural weeding-out before thinning is done. Otherwise, unknowingly, the weak or diseased seedlings may be left.

Some results of experiments on early and late thinning are available. In one case, beets thinned when they had two to four leaves yielded 1¾ tons more per acre than beets thinned when they had eight to ten true leaves, and 3½ tons more per acre than beets thinned when they had twelve to fourteen true leaves.

Thinning should be started promptly and pushed to as quick a conclusion as possible while soil and weather are favorable. Too frequently, through delay, the beets in a part of the field become so large that they suffer from the shock of thinning.

The statements given above concerning the age for thinning apply particularly to mineral soils. Although there are no experimental data, certain growers have observed that thinning can be delayed much longer on peat lands than on mineral soils, without injury to beets. They even state that thinning should be delayed, claiming that unless the young beets on peat soils have a well-established root system at thinning time, the roots of the seedlings left may dry out in the soil which has become loosened as a result of its disturbance in thinning. Apparently, moreover, less twisting of roots of closely adjacent plants occurs in loose soils than in heavier soils.

Spacing Beets, and the Influence of Stand on Yield.—The basic consideration in the spacing of sugar beets is the soil volume in which the plants absorb water and plant nutrients. Obviously the spacing in the row can be somewhat closer when the rows are 22 inches apart than when they are 18 inches apart.

TABLE 6

ACTUAL YIELD OF BEETS WITH GOOD AND WITH POOR STANDS AS COMPARED WITH THEORETICAL YIELD ON BASIS OF 100 PER CENT STAND OF NORMALLY COMPETITIVE BEETS

Field	Stand at harvest	Yield of roots per acre		Sucrose percentage
		Actual	Theoretical*	
	per cent	*tons*	*tons*	*per cent*
A	99	14.81	14.76	18.08
	66	10.04	14.89	17.46
B	84	17.80	20.90	18.12
	67	13.26	19.60	17.38

* Calculated on basis of 100 per cent stand of normally competitive beets; for explanation of latter term, see footnote 4, p. 32.

No iron-clad rule can be laid down regarding the distance beets should be thinned to cover all the various conditions conceivable. Crowding beets reduces the amount of light coming to the individual plant and also the soil volume in which the plants feed. In unnecessarily wide spacing, the land is not working to full capacity. A wide stand reduces, whereas a close stand tends to increase the sucrose percentage in the beet. If the beet plant has ample room for growth and development, it becomes large at the sacrifice of sucrose percentage; if it is crowded by close spacing, its size is reduced, but the sucrose percentage is relatively high. Moreover, closer spacing tends to produce beets of uniform size and shape.

It has been fairly well demonstrated on the fertile peat soils of the Delta that more sugar to the acre can be secured through closer spacings than has been secured in the past by ordinary 20-inch rows and 12-inch spacing.

In 1931 two fields of sugar beets in southern California were selected for comparison of the effect of poor stands on the yield of sugar beets. For convenience they are designated as fields A and B. In each field 10 plots were established. The plots were 8 rows wide and 65 feet long; and the distance between rows was 20 inches. Stand counts were made in each plot in both fields, and the 10 plots in each field were then divided into two groups: one in which there was a poor stand and one in which there was a good stand. At harvest the total beets in each plot were weighed, and also all normally competitive[4] beets in each plot.

The value for weight per beet was then computed and multiplied by the number of beets per acre that would have been present in a 100 per cent stand. Table 6 represents the data obtained from these comparisons.

Table 6 shows that in both fields the larger yields were obtained in the plots where a good stand was present. The yield in the plots with a poor stand would have been approximately 4 tons per acre more if the stand had been equal to that in the plots where a good stand was obtained. The theoretical yield indicates that the soil on plots having poor stands was potentially capable of yields about as high as that of plots having good stands. There was no compensating gain in sucrose percentage in the plots with a poor stand.

TABLE 7

SUMMARY OF RESULTS OF DISTANCE-OF-SPACING TEST, CHINO, CALIFORNIA, 1932, WITH A DISTANCE OF 20 INCHES BETWEEN ROWS

Distance of spacing, in row	Yield of roots per acre	Sucrose percentage	Calculated gross yield of sugar per acre
inches	*pounds*	*per cent*	*pounds*
6	35,744	16.4	5,862
8	31,966	16.4	5,234
10	30,855	15.9	4,934
12	30,744	15.8	4,866
14	27,100	16.5	4,472
16	26,944	16.4	4,419
18	27,000	15.5	4,208
20	24,955	16.2	4,036
22	24,555	16.2	3,989

Tests have been conducted at Chino, California, for three years, to study the effect of spacing on yield, sucrose percentage, and purity of sugar beets. Table 7 gives the results for 1932. The date of planting was January 26, 1932, and the date of harvest August 2, 1932. These tests included nine different distances of spacing within the row—6, 8, 10, 12, 14, 16, 18, 20, and 22 inches. There were nine plots for each treatment. The plots were four rows wide, 65½ feet long, and with 20 inches between rows. As the data in table 7 clearly indicate, beets spaced 6 and 8 inches give significantly higher yields on this soil that those farther apart.

In the discussion given above, reference was made to the stand at *harvest*, not the stand at *thinning*. As is well known, beets are lost be-

[4] By "normally competitive beet" is meant one 20 inches distant from neighbor on each of two sides and 12 inches distant on the other two.

tween thinning and harvest. This loss may result from poor soil conditions at the time of thinning, causing the death of plants the first few days after thinning; from the cutting out of beets by the hoe or cultivator; from poor irrigation; or from the attacks of insect pests or fungus diseases. Experience has shown that an average loss of 7–10 per cent in stand can be expected between thinning and harvest. If, therefore, one expects to harvest a 12-inch stand of beets, one should strive to leave approximately 120 uniformly spaced beets to 100 feet of row at time of thinning; that is, a beet every 10 inches.

Successful beet growers in this and European countries tend toward a closer spacing of beets than has been the practice in the past. The aim is a larger number of uniformly spaced beets, resulting in beets of uniform size. Uniformity of stand is a most important consideration. Generally speaking, closer spacing gives increased yields.

There are often blanks or "misses" in the germination stand. In this event, there should be an effort to make up for these by spacing the beets closer immediately on either side of a blank space in the row. This will mean, when a 12-inch spacing is attempted, that there will be some beets 6 or 8 inches apart in the row. This practice in thinning results in a larger number of beets to the acre; and although the closer spacing here and there reduces the size of the individual beets which are crowded, the total yield per acre is increased. The method of thinning just described is particularly useful in fields where the germination stand is uneven or where there has been destruction of seedlings by disease or cold weather.

Growers and those who have carefully studied the results of instructions given to labor find that in general the stand left by the thinner is usually somewhat wider than that asked for. For example, if labor is instructed to leave a 12-inch stand where such a stand can be secured, one may expect a spacing of 13 or 14 inches.

The foregoing discussion has been based on a distance of 18 inches between rows. There may be conditions under which it is desirable to have a greater distance between rows. In such cases, the distance between beets in the row should be less than 12 inches. When rows are 20 inches apart, for example, a spacing of 10.8 inches in the row gives each beet as much soil volume as when the rows are 18 inches apart and the spacing in the row is 12 inches.

Selective Thinning.—It is a common observation at harvest time that there is a great diversity in the size of roots. Moreover, it is well known that there is great variation in the size and vigor of the different seedlings in any germination stand. What are the reasons? In the first place, there is much variation in the size of the beet seed balls. In the second place, the different seeds in a seed ball vary considerably in size. But more important than the size of the seed ball or of the seed is the vigor of the germs or young plants within. Their vigor has been found to depend upon their weight; the heavier germs probably contain a greater amount of reserve food. The heavier and more vigorous germs produce larger seedlings at thinning time, and this difference apparently continues throughout the life of the plant. Great variation has been found to exist between the different individuals arising from a single seed ball. This fact should be recognized in thinning and care be exercised to leave the large seedling.

The experiment station of the Great Western Sugar Company has for several years been comparing the development of beets produced by large and by small seedlings. At the time of thinning, a number of beets, larger than the average and designated "large," were selected. They were given the same culture throughout the season, and careful measurements were made throughout the life of the plants. The results were:

1. The large seedling develops into a larger beet at harvest than does the small one.

2. The percentage of beets dying is usually greater among those which are small at thinning than among those which are large.

3. The total sugar of beets from large seedlings slightly exceeds that of beets from small ones.

4. The ratio of tops to roots is smaller in the case of beets from the large seedlings than in that of beets from the small seedlings.

Similar tests were conducted for two successive seasons (1926–1927) at the University Farm, Davis, California. In both years, the yield of roots from large seedlings was approximately 35 per cent greater than that from small.

It is well demonstrated that increased yields result from leaving the large seedling at thinning and that the extra cost in labor necessary is compensated for several times over. There is no easier way to increase profits from a beet crop than to leave the largest and healthiest beets.

Methods of Work by Thinners.—Almost all thinning of beets in California is done by Mexicans, together with a few Filipinos, Japanese, and Hindus. These workers use a short-handled hoe, crawling along the rows on their hands and knees. Usually a worker takes two rows at a time; each does his own blocking and thinning. Generally speaking, there is much room for improvement in their method of work. Observation of their methods shows many glaring faults, which should and can be corrected. Some workers, by carelessly dragging a foot or knee along a row, destroy many plants. Others tend to cut too deeply with the hoe, removing an unnecessarily large amount of soil from the row and from around the beets. Often a trench is left down the row, with sharp sides made by the cut of the hoe; and the young plants, with much of their roots exposed, remain prostrate and dangling. The young beet should not be left standing on a small block of earth which will dry out rapidly at the sides. By the proper use of the hoe, the surplus beet plants and the weeds are cut off, and the soil and the desired beets are left in their original position. The cut made by the hoe should be only deep enough to come below the crown of the plants to be removed.

Many thinned beets die in the scorching sun because, as related above, they have been left dangling by a mere thread of a root, with the soil drawn away from them by the hoe. The plant should be disturbed as little as possible and kept erect. Soil should be pulled around the root of each beet which is left at thinning. This is indeed an important factor in securing an increased yield.

Some workers use an unnecessarily wide hoe. The greater speed made with such a tool is most certainly at the price of reduced yield. Closer spacing will be secured if the hoe blade is not over 6 or 7 inches wide. Several very successful growers in the Delta region, on loose peat soil, do not allow a hoe in the field. It is possible, in this very loose soil, to block and thin with the hands. This method is to be recommended in soils that make it possible.

In the case of contract labor, speed is uppermost in the mind of the worker. Almost always, as a consequence, the beet crop suffers. The thinner attempts to cut out, rather than pull out, as many beets as possible and, in doing so, often widens the spacing or cuts too close to the beet he wishes to leave. Moreover, he is making a slash with the hoe ahead of him in the row, with his eye directed forward while with his other hand he is blindly feeling his way in the small block of beets just left in an attempt to remove all but one beet from this block. In this operation he all too frequently removes the largest beet, which is the one most easily grasped, or he leaves "doubles."

As stated above, many workers attempt to block and thin two rows at a time. Field experience demonstrates conclusively that better stands are secured when one row at a time is blocked and thinned, for then the worker's attention is more concentrated on his job.

The method of thinning beets employed in Europe, in certain parts of the Middle West, and in some Rocky Mountain states is one involving two distinct operations. These are (1) blocking or spacing and (2) thinning proper. Blocking is done with a long-handled hoe; thinning is done by hand. This method appears superior to that commonly practiced in

California: it has a tendency to compel the thinners to leave a beet in the block, the stand is usually more uniform, and the spacing can be performed when the beets are still too small to be thinned.

Blocking should precede thinning by several days. During this interval, the plants cut out wither, and this makes the blocks more visible. In blocking, moreover, a certain amount of competition of seedlings is removed, and the plants left standing in the blocks can make more rapid growth. By thinning in two operations, each worker has but one operation to think about. The blocker can give his undivided attention to spacing; the thinner, working as he does without a hoe, can direct his attention to thinning each block and leaving in it the largest and most thrifty beet. Blocking and thinning in two operations cost slightly more than when done simultaneously, but the increased yields more than compensate for the extra cost. It will be a distinct step forward in California beet culture if the long-handled hoe is generally adopted, and thinning is done in two distinct operations. Once labor has become accustomed to this method, it will be reluctant to go back to the present practice.

Doubles.—When two beets grow very close together, the development of both is often hindered, and their combined weight usually does not equal the weight of one beet left standing at that point. In some soils, particularly heavy ones, the roots of doubles coil about each other. Apparently doubles in the lighter types of soil are not so detrimental as in heavier soils. In such soil types the loss from doubles is often overestimated, and the grower should not quarrel too much with labor about such doubles, if they are not too numerous. Doubles should be removed with the hand; it is better to leave them than to attempt their removal with a hoe. Many times the laborer cuts off both plants, instead of one, when he tries to remove one with the hoe. Care should be taken to leave the healthier and larger of the two plants.

Supervision of Labor.—Probably no other single effort on the part of the sugar-beet grower will bring such large returns as the proper instruction and supervision of labor at the time of thinning. Not only should definite instruction be given on how to thin and why, but the quality of the work must be checked frequently, for one cannot assume that because laborers have been started right, they will continue as first directed. Carry a measuring tape into the field and frequently check up on the number of plants that are being left per 100 feet of row.

The grower need not stand over laborers like a section boss; and his supervision need not be harsh criticism. Laborers must be treated as human beings. But the grower must be in the field every day and if possible make a careful and actual check of the work. Laborers will be careless and indifferent if the grower is. They will do satisfactory work if properly instructed and supervised.

Many growers leave the job of supervision to the sugar-company fieldman, but he has many fields to look after and cannot give such close attention as the grower.

Incentive to the Beet Worker.—Many growers and sugar companies stimulate a better quality of labor by offering bonuses or prizes. In one beet territory many growers insert in the contract a bonus clause, which provides that the grower will pay, in addition to the regular basic rate, an extra sum per acre for each ton more than an average yield of a certain specified number of tons per acre. This requires the determination of the percentage of stand before and after thinning, but the additional effort is justified by the better stand of beets that finally remains.

Cross-Blocking of Sugar Beets by Machine.—Mechanical blocking (fig. 13) as a substitute for hand-blocking has been demonstrated as a practical method in most of the sugar-beet territories. It has met with the approval of hundreds of growers.

The usual type of cross-blocking machine is an ordinary beet cultivator with the tools spaced so that blocks of beets of the required size and spacing are left undisturbed when the machine is drawn across the beet rows (fig. 14). Markers, like those used on a beet drill, are necessary. The type of soil will determine the kind of tools.

In clean sedimentary soils, ordinary knives or duckfeet flat enough to avoid throwing soil over the seedlings may be used. Adjustable knives (fig. 15) of variable width of cut and flatness of blade now on the market are very satisfactory for cross-blocking as well as for ordinary cultivation.

In moderately loose or trashy soils of the sedimentary type, disks may be needed along with the knives (fig. 16). An odd number of knives should be used so that the one in the center will cut out the marker track and the track of the rear wheel. The front cultivator wheels should be so set that knives also cut out their tracks.

In the very loose peat soils, no setup that does satisfactory mechanical blocking has thus far been arranged. In these soils clogging the tools with loose soil and trash is difficult to avoid.

The spacing of the tools should be adjusted to the germination stand. If the stand is poor—that is, if only 20 to 30 per cent of inches of row contain seedlings—the nearest approach to a 12-inch spacing will be secured by setting the knives to leave a 4-inch block and cut out a space 6 inches wide. If the stand is good—that is, if 40 to 50 per cent of inches of row contain seedlings—such a setup will leave approximately 100 beets

Fig. 13.—Cross-blocking sugar beets.

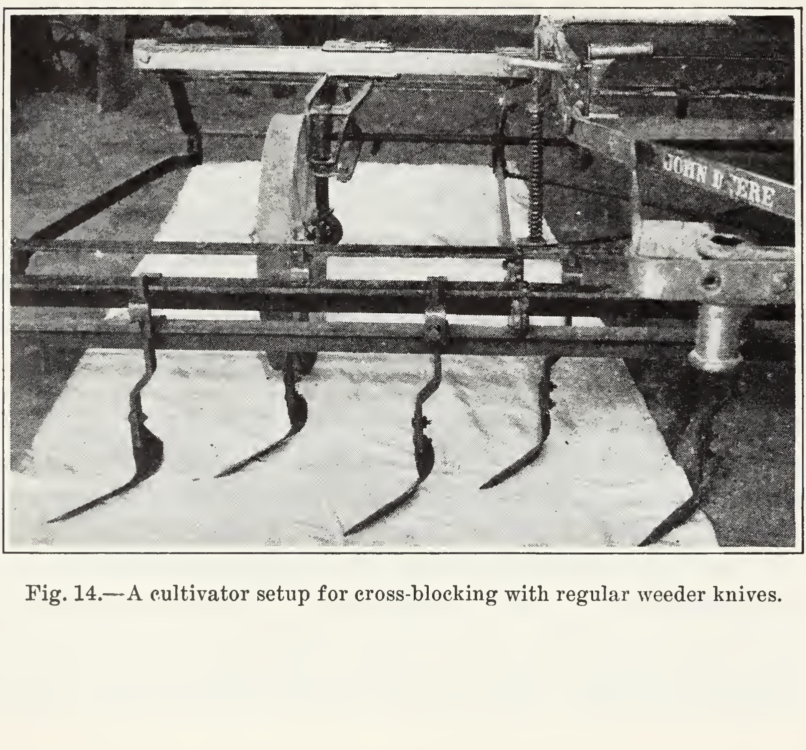

Fig. 14.—A cultivator setup for cross-blocking with regular weeder knives.

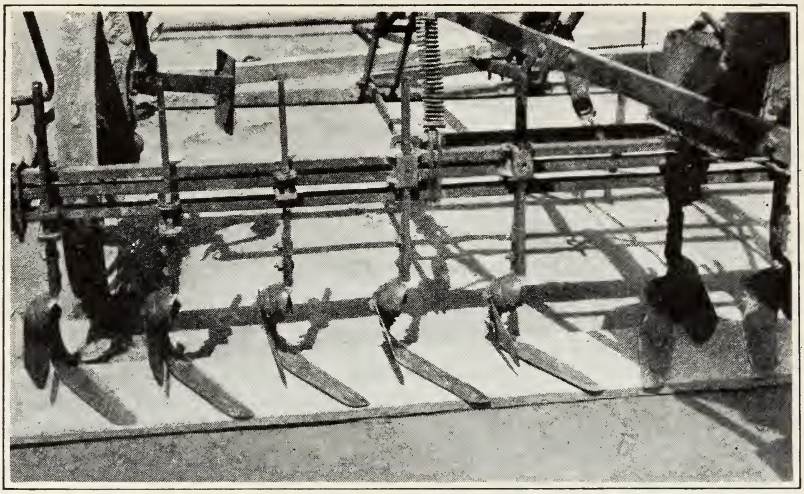

Fig. 15.—A cross-blocking setup using adjustable knives.

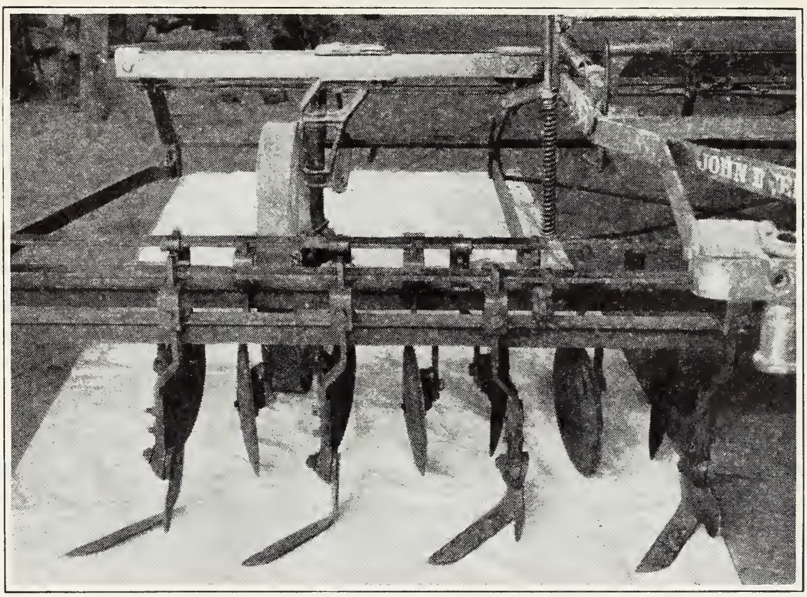

Fig. 16.—A disk and weeder-knife setup for cross-blocking.

per 100 feet of row. If the stand is excellent—that is, if 60 to 70 per cent of inches of row contain seedlings—then the blocks of beets left may be much smaller and still leave 100 beets to the 100 feet of row. There is advantage, of course, in leaving the block as small as possible, for in such case there is less work for the thinner and more cultivation in and between the rows.

According to carefully conducted experiments and growers' tests over a wide territory, mechanical blocking equals or excels hand-blocking. A series of tests conducted coöperatively by the Bureau of Agricultural Engineering and the Division of Sugar Plant Investigations, both of the United States Department of Agriculture, gave the following results, the spacing being 12 inches between blocks:

	Machine	Hand
Blocks per 100 feet of row after machine	90.4	...
Individual beets per 100 feet of row after thinning	81.6	91.1
Yield, tons per acre	19.5	19.5
Per cent time saved	31.95	...

In another series of tests, with a spacing less than 12 inches between blocks, the following average results were obtained:

	Machine	Hand
Blocks per 100 feet of row after machine	100.9	...
Individual beets per 100 feet of row after thinning	100.7	105.9
Yield, tons per acre	15.6	15.5
Per cent time saved	23.7	...

The advantages of mechanical blocking as compared with hand-blocking are as follows:

1. In case of shortage of labor or unfavorable conditions, resulting in an unavoidable delay in thinning, mechanical blocking may avoid losses.

2. Mechanical blocking is a good cross-cultivation: it removes weeds in the rows, together with a majority of the surplus beets, and thus greatly reduces competition and enables the beet seedlings in the remaining blocks to progress more rapidly.

3. Mechanically blocked beets recover more rapidly than do hand-blocked beets, because less soil is taken away from the plants.

4. Mechanical blocking can be done earlier than hand-blocking, while the beets are younger; this results in less disturbance to the seedlings. As experiments show, the mortality of seedlings after mechanical blocking is less than that after hand-blocking.

5. Mechanical blocking effects a saving of time. The total cost of mechanical blocking and thinning, moreover, is less than that of hand-blocking and thinning.

6. If a field is infested with wireworms, or plants are affected by seedling diseases, blocking and thinning in two operations is advantageous.

Only in severe cases will all the beets in a block be lost. Hence there is opportunity for selective thinning that avoids infected seedlings.

If the grower contemplates mechanical blocking, the rate of seeding must be ample to insure a good germination stand. If the germination stand is satisfactory, there need be no difficulty in securing the desired thinned stand by mechanical blocking. As a rule one cannot expect that good hand labor will be more than 90 to 95 per cent efficient in blocking and thinning. In other words, do not be unduly alarmed if skips occur here and there as a result of mechanical blocking, for even the best labor usually leaves some skips in the row.

IRRIGATION

The sugar beet requires large amounts of water to produce a satisfactory yield. A farmer should not attempt the growing of beets unless he is assured an adequate and continuous supply of water up to within a few weeks of harvest time.

Most of the water that enters the beet plant from the soil passes out through the leaf pores (stomata) to the air; some of it is used by the plant, chiefly in growth and in manufacturing sugar. The sugar-beet crop requires a rather large amount of water to bring it to maturity—as much as 20 to 24 acre-inches (rainfall and irrigation water) during the season. According to the experience of growers, best yields are obtained if the beet plant is never permitted to suffer from lack of moisture during its actively growing period. Water must, furthermore, be available in the deeper layers of soil so that the roots will at all times find suitable moisture conditions under which to develop. Except in soils where the water table is naturally high, beet roots reach a depth of 5 or 6 feet if proper moisture conditions prevail at these levels. The root system of a mature beet growing under favorable soil-moisture conditions may occupy a soil volume of 125 to 150 cubic feet. At proper thinning time—that is, when the plant has four true leaves—the taproot has reached a depth of 12 to 18 inches, under favorable soil-moisture conditions.

Certain beet farmers still believe that if water is withheld even to the point of causing the beets to suffer, the roots are "driven down to water" and thus a longer beet is produced. Experiment after experiment, substantiated by field tests, has fully demonstrated that that is erroneous, that normal growth takes place only when all roots have a moist soil in which to develop, and that the best performance of the plant as a whole, as represented by both root growth and sucrose percentage, occurs when its growth is uninterrupted and continuous throughout.

Do not wait until the plants are wilted before applying water. Rather, apply frequent light irrigations to prevent wilting. On hot, dry days, when water loss from the plants is excessive, temporary wilting may occur. This may not mean an actual deficiency of water in the soil. It does mean that for a certain period of the day, water outgo from the leaves exceeds water intake from the soil. Such plants usually recover fully during the night; should they not do so, the danger point has been reached.

In some instances, water is withheld until the foliage is seriously injured. Then, when it is added, loss from root rot is stimulated.

Beet growers have found, as a rule, that the first irrigation should not be delayed. The time, of course, depends upon the winter rainfall. It is well to furrow out and to have all lateral ditches made well in advance, and to schedule the first irrigation early, even though the plants show no signs of water shortage. Often a grower with a considerable beet acreage finds that many beets in the field wilt before the first irrigation is completed. This is improper irrigation management.

The first irrigation should not only be early but, as a rule, rather heavy, in order to bring the soil, to a considerable depth, to its field capacity. If, however, winter rainfall has been heavy, the first irrigation may be relatively light. The essential point is that the first and each subsequent irrigation should be of an amount that will bring up to field capacity the total volume of soil that is occupied by the roots and into which they are penetrating. At no time during the growing season, moreover, should the amount of water in the soil be allowed to get below a point that results in the wilting of plants day after day. The depth to which water penetrates the soil can be judged with a soil auger. Frequent examination should be made to determine the moisture condition of the lower soil layers.

No rule can be given as to the proper number of irrigations for a sugar-beet crop. Under certain conditions two irrigations may be enough; under others, five or more. Do not irrigate by the calendar. Soil, weather, and crop conditions, not the calendar, determine the frequency of irrigation and the amount of water to apply each time.

Furrow irrigation (fig. 17 *B*) with short runs insures the best use of water. On sandy lands the runs should not exceed 400 feet; on heavier soils, 600 feet. A small head of water, run slowly to permit soil penetration, is recommended. In some sections short lengths of pipe (fig. 17 *A*) are used that lead the water from the laterals to the rows of beets, a method insuring a uniform and slow distribution of water in each beet row.

The flooding of sugar beets should be discouraged. As a usual result, certain parts of the field receive too much water. When water stands around the crown of a beet on a hot day, scalding of the crown is certain to follow, and eventually a rotting of the entire root. In the beet-growing sections where cooler temperatures prevail, flooding may not be so dangerous; but in any case is is very inferior to careful furrow irrigation, for even in the coastal areas flooding of heavy land often results in the loss of tonnage through rotting of beets. Moreover, in fields irrigated by

A *B*

Fig. 17.—*A*, Short sections of pipe used to direct the water from the lateral ditches to the rows of beets. *B*, Furrow irrigation; the water should not be allowed to come in contact with the crowns of the beet, especially on hot days.

the furrow method, or ridge-planted, the soil surface dries out more uniformly than when flooded, and therefore permits a cultivation sooner.

For proper furrow irrigation, well-leveled land with uniform slope is essential. The cost of irrigating uneven land over a period of years is often greater in the end than the initial cost of leveling. If a grower has a considerable acreage to level and cannot accomplish this operation all in one season, he might well level a portion of the area each year and thus gradually bring the whole into a satisfactory condition. Once a tract of land is properly leveled, it can be kept so at a low cost each year.

A point much discussed is the effect of an irrigation practice, particularly the timing of the last irrigation, upon the sucrose percentage in the beet. In certain cases the last irrigation is made 6 to 8 weeks before harvest, with the thought that this procedure insures a satisfactory sucrose percentage. In such cases the percentage may indeed be increased; but the loss to the grower, as a result of decreased tonnage, is often greater than his gain from increased sucrose percentage. In most beet areas, the last irrigation should be given about 2 to 3 weeks before harvest, although, as stated above, it may be given a month or more before harvest. If a beet has been kept growing without interruption throughout the

Fig. 18.—Portable sprinkler system in operation in Reclamation District 1660, near Meridian.

growing season, it will mature normally despite a late irrigation, although such irrigation may postpone the date of maturity. The harm from a late irrigation comes when the beets have lacked water to the extent of injury to both foliage and roots, so that new growth is stimulated and consequently the sucrose percentage is lowered.

In dry seasons, with uncertain rainfall, it may be highly advisable to irrigate the beet stands up. Thus the growth may be advanced from two weeks to a month, and a good stand is assured. This early growth may substantially increase the tonnage. An advantage of ridge or bed planting is that it is possible to irrigate the beet stands up without injury to the stand by blind furrowing. Likewise, a distinct advantage of sprinkling, or overhead irrigation, is that a good stand is assured.

In the flat peat lands of the Delta, subirrigation is almost universal. These flat lands do not permit furrow irrigation. Within the last few years, however, limited acreages have been irrigated by the overhead system, often with satisfactory results. Where, because of the small water lift, the costs of pumping water and applying it thus are reasonable, this method has much in its favor. Subirrigation over a period of years usually results in the accumulation of salts in the upper soil layers, so that it becomes difficult to secure good germination stands, and the sucrose percentage in the beets may be depressed. The ill effects of subirrigation are particularly noticeable if the winter rainfall is so low that there is not sufficient leaching of the salts from the surface layer of soil. Overhead irrigation of peat soils, when coupled with adequate drainage, has the distinct advantage of keeping the movement of salts downward.

The water table of subirrigated lands is often kept too high for the best development of the sugar beet. A high water table limits the root

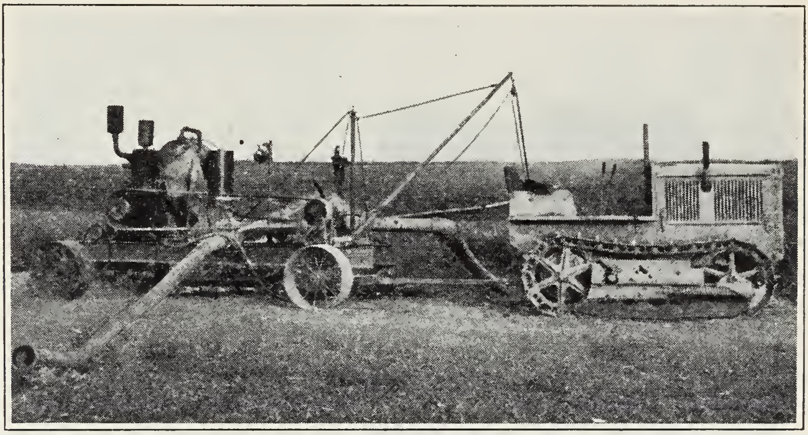

Fig. 19.—Pumping plant for portable sprinkler system consisting of 20-hp. Diesel engine and 4-inch centrifugal pump mounted on a trailer and drawn by light tractor.

zone of the beet and causes short, stubby roots with many "sprangles." Judging by field experience, after each subirrigation, which is accomplished by raising the water table to within 6 to 12 inches of the surface, the water table should promptly be brought down to a level of 4 to 6 feet. Then the beet root system will have an opportunity to develop its normal form.

Irrigation of Sugar Beets by Sprinkling.[5]—The irrigation of sugar beets by sprinkling (or overhead irrigation) is relatively new. It has been made practical by a portable sprinkler system (fig. 18) costing $10 to $30 an acre, including pipe, sprinklers, and pumping plant (figs. 19 and 20). Permanent or stationary systems generally cost $200 to $500 an acre. While offering some of the same general advantages, portable systems permit a more uniform distribution of water.

An ideal irrigation method is one by which water can be applied uniformly in sufficient amount, without waste, at the lowest possible cost.

[5] This and the two following subsections were contributed by J. E. Christiansen, Junior Irrigation Engineer, California Agricultural Experiment Station.

With any method, in practice, a certain amount of waste always occurs. Waste may be considered as the water applied which is not subsequently transpired by useful plants or retained within the soil occupied by roots. Deep percolation, surface runoff, and evaporation are the chief forms of waste.

Unless the water table is within the reach of the roots, deep percolation can be avoided only by limiting the depth of application to the amount that will be retained within reach of the roots. A uniform appli-

Fig. 20.—Large portable pumping plant: 50-hp. Diesel tractor operating 5-inch centrifugal pump; two lines of pipe totaling 2,480 feet with 6-foot sprinklers. The total discharge is approximately 1,100 gallons per minute.

cation is therefore essential if such waste is to be reduced to a minimum. Undoubtedly this is the greatest waste of water by most methods of irrigation, largely because the loss is invisible. Sprinkling permits water to be distributed with a fair degree of uniformity—possibly better than in most surface methods of irrigation.

With proper land preparation and care in irrigating, surface runoff can be entirely avoided.

Evaporation loss is confined largely to the first 6 or 8 inches of soil and usually amounts to less than an inch of water between irrigations. This is a relatively small portion of one application as usually made by surface methods. The loss is very rapid immediately after an irrigation but becomes almost negligible after about two weeks. When light, frequent applications are made by sprinkling, a large percentage of the water applied may be evaporated. In addition, considerable loss occurs during the application. According to tests, during the afternoon of a hot day as much as one-third of the water may evaporate before reaching the ground. Though the loss by deep percolation is largely under control by sprinkling, the loss by evaporation may be appreciable. This loss, however, may be less than the loss by deep percolation and runoff under surface-irrigation methods.

As compared with most other systems of irrigation, sprinkling is expensive. The cost of applying water by surface methods varies greatly and depends primarily upon the topography, the land preparation, the irrigation system, and the size of the stream available. The cost of sprinkling depends not so much on topography and land preparation as upon the capacity of the system and the method of using it. This cost is made up of the following major items: labor, power, interest, depreciation, and maintenance.

The labor cost ranges from about 25 cents to $1.00 per acre-inch, the power cost from about 5 to 40 cents. The interest, depreciation, and maintenance are difficult to estimate but will probably range from about 25 to 50 cents an acre-inch. Although the total cost of sprinkling may in some cases be only 60 to 75 cents an acre-inch, the average cost for systems in use exceeds $1.00 an acre-inch. When the irrigation requirement for sugar beets is 20 to 24 inches a year, as in the interior valleys with a water table 10 feet or more below the ground surface, sprinkling is obviously expensive.

Conditions Under Which Sprinkling Is Desirable.—Under certain conditions, sprinkling is especially desirable. It is probably adapted to a wider range of physical conditions than any other method and is usually suitable where other methods fail to achieve the desired results or are excessively costly.

Sprinkling has been found particularly desirable in the Sacramento–San-Joaquin Delta on both silt and peat soils. This area is very flat, and subirrigation is generally practiced. Because of minor surface irregularities and insufficient slope, surface irrigation is difficult. According to the general opinion of the growers, somewhat better yields have been secured with sprinkling.

Since the crops grown in this section are able to obtain a large portion of the water they transpire directly from the soil zone just above the water table, the irrigation requirement is low, and only relatively light applications are required. The amount usually applied by sprinkling during the season varies from about 8 to 15 inches. A relatively larger area, consequently, can be cared for by a given system at a correspondingly lower cost. This is also true in the coastal areas where the irrigation requirement is low. Under such conditions the annual cost of sprinkling compares very favorably with that of surface irrigation.

Sprinkling is also well adapted to rolling topography and virgin land where a considerable expense in leveling would be necessary for surface irrigation. Soils which retain a relatively small amount of water available to plants and which must therefore be frequently irrigated are particularly suited to sprinkling. Usually these soils are very porous, and considerable waste results from surface irrigation.

Advantages and Limitations of Sprinkling.—Some advantages of sprinkling are difficult to evaluate. In certain cases, it may be considered as crop insurance. During unfavorable weather conditions, one can sometimes make a light application before beets are up and thus secure a good stand when otherwise a replanting might be necessary. Beets can also be sprinkled while they are still very small, before surface irrigation is desirable. This may be a decided advantage after the periods of hot, dry winds that frequently occur during the early spring months.

A sprinkler system provides an effective and economical method of applying commercial fertilizers in solution and assists proper distribution of fertilizer materials through the soil.

The elimination of ditches and levees in the field is another attractive feature. Besides saving the area thus occupied, sprinkling eliminates the resultant weed problem and facilitates all cultural operations.

Sprinking is limited primarily by its cost. Other practical difficulties, however, limit the use of portable sprinkler systems. To avoid runoff and puddling of the soil, the water must be applied at such a rate that it will not accumulate on the surface. The lower the rate of application, the smaller the area that can be covered with a given length of pipe. Heavy clay soils may require such a low rate of application as to make sprinkling impractical. Often such soils are so muddy after an application of an amount sufficient for the desired penetration that the pipe cannot easily be moved for several hours. Thus the area that can be covered is limited. To avoid such difficulties light applications are usually made, and in some cases the soil below the first foot or 18 inches remains dry throughout the season. Some failures of sprinkler systems can be attributed to this cause.

HARVESTING SUGAR BEETS

The harvesting season in California begins when sufficient beets are mature to keep the factory in the district operating at full capacity. The length of time the factory operates will depend upon the acreage and upon the capacity of the mills. Maturity of beets is determined by laboratory analyses of samples of roots from the field.

After the sucrose percentage has been determined by the sugar-company chemist, the grower is advised as to the condition of his crop. He should not attempt to increase the sucrose percentage of his beets by excessive drying-out, for such an increase usually does not compensate for his loss in tonnage. In cases of extreme drying-out, indeed, sugar may actually be lost from the root through its use in certain life processes.

It has been a practice in certain territories to lift the beets one, two, or three days before topping and to leave them standing loose in the soil.

Fig. 21.—Four-row beet plow.

There is, under these conditions, an appreciable gain in sucrose percentage; but the loss in weight and the poor condition of the roots as a result of drying make the practice of questionable value. The grower should aim to deliver solid beets in good condition, and the practice of predigging may defeat this aim.

The method of lifting the beets from the soil varies somewhat with the cultural practice, the type of soil, and the equipment available to the individual grower. In some sandy soils a small type of beet puller is used. Usually it is drawn by horses and pulls only one row at a time. It is often entirely inadequate for use in heavy soils.

Lifting plows similar to the one shown in figure 21 are used in certain sections of California. Such a plow lifts four rows of beets at a time. The depth at which it is run depends upon the length of the roots. The side wings fastened securely to the puller points serve to cut the beets off at the tip end. Care must be taken to adjust the depth of the plow so that the whole beet is harvested except possibly the small root tip. Very often the loss of beets through careless operation of the plow will exceed the cost of pulling. The plow should therefore be kept in good mechanical condition, and the operator should examine the pulled beets frequently to see that they are not being broken or cut off. Several other types of plows and pullers are in use. Each grower has his individual problems and chooses his implement accordingly.

A number of mechanical pullers and plows have been developed in the past, some of which pull, top, and load the beets in one operation. These machines are not as yet in general use. With the usual method, the beets are lifted from the soil by the puller or plow; and the laborers pick them up, remove the tops, and throw the beets either in piles or in windrows to be loaded in wagons or trucks. In some sections the beets are loaded with forks; but in California this method has been largely replaced by hand loading, which has the advantage of eliminating clods and leaves from the load. The beets are transported in wagons or trucks to the loading stations, to be placed in railroad cars and taken to the factory. Beets grown nearby are hauled direct to the factory bins.

FERTILIZING SUGAR BEETS

Of the many chemical elements taken in by the beet plant, the most essential are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, magnesium, calcium, sulfur, and iron. Carbon enters the plant in the form of carbon dioxide gas, through the pores of the leaves. Hydrogen is supplied from water. Oxygen comes in as such through the leaf pores and also in the compound, water.

The remaining chemical element—nitrogen, phosphorus, potassium, magnesium, calcium, sulfur, and iron—enter the plant through the roots in the form of mineral salts, which must be in solution before they can be absorbed. The chief nitrogen-containing compounds in which the nitrogen is available for plant use are the nitrates and certain ammonium salts. Phosphorus enters the plant in the form of a phosphate, sulfur in the form of a sulfate, and iron in various compounds. Potassium, iron, magnesium, and calcium enter in the form of various salts, such as phosphates, nitrates, chlorides, and sulfates.

Since soils vary widely in their ability to produce crops and since they do not respond alike to fertilizer treatment, no system can be outlined that will be equally effective on all soils. As stated, certain elements are known to be essential to the normal growth of crops. In some cases enough of these elements occur in the soils, but in a form not available to the plants. In such a case, adding the elements in the form of commercial fertilizer often gives no beneficial results because they become unavailable to the plant by entering into chemical reactions with constituents of the soil. Soil fertilization, therefore, is a very complex problem. Well-planned, long-time field experiments with the crops in question are required. Frankly, most fertilizer experiments with sugar beets in California soils have been inadequate to be of material assistance in fertilizer problems.

Most California soils in which sugar beets are grown, except the peat soils of the Delta, are deficient in organic matter. As is well known, the soil must contain organic matter if there is to be proper bacterial action. Growers recognize that animal manures added to the soil increase the yield of sugar beets. In general, however, insufficient barnyard manure is produced on the ranches of California to supply the fertilizer needs; and consequently this material must be supplemented with green-manure crops that are plowed under. Scattered field tests in California seem to indicate strongly that green manures should be seriously considered by the sugar-beet grower. On page 7 the beneficial effects of a green-manure crop in Ventura County are described.

Effect of Commercial Fertilizers on the Yield of Sugar Beets.—As stated, the use of commercial fertilizers on sugar beets has not been general in California, and for the most part the tests have been inadequate. A few carefully planned tests by both sugar companies and growers, however, have been conducted in recent years on different soil types to determine the value of different fertilizer mixtures when applied to the sugar-beet crop. In some cases, a fertilizer predominantly high in nitrogen applied as a side dressing after the beets have been thinned has significantly increased the yields. More work on this particular phase of sugar-beet fertilization must precede any definite recommendation. This work is now being done by the United States Department of Agriculture, coöperating with the California Agricultural Experiment Station. The sugar companies are either assisting in this work, or conducting tests themselves. The results will be made available later.

In the Chino area, tests with commercial fertilizers, begun in 1927 and continued since that time, have shown that fertilizers predominantly high in phosphoric acid, applied with the seed, have increased yields of sugar beets as much as 11 tons per acre. According to these tests, 200 to 300 pounds per acre of superphosphate containing the equivalent of 20 per cent phosphorus pentoxide, applied with the seed, is utilized by the crop most efficiently. Some phosphate fertilizers on the market contain a larger and some a smaller percentage of phosphorus.

The application of this material with the seed requires a beet drill equipped with fertilizer attachments. As the growers in the Chino area did not have such drills, the question arose whether or not this material could be broadcast with equally good results. Field tests were designed to determine the best method of application, and unfertilized plots were included to ascertain the benefit derived from the superphosphate fertilizer. These tests were begun in 1932 and repeated in 1933. Table 8 shows the methods used and the two years' results. These tests, conducted at Chino, California, on soils responding to an application of phosphate fertilizer, showed that application with the seed was more efficient than the broadcast method. In these tests, 200 pounds per acre of superphosphate drilled with the seed was practically equal to 400 pounds of fertilizer broadcast.

TABLE 8

Results Obtained from Different Methods of Applying an 0–20–0 Superphosphate Fertilizer to Sugar Beets at Chino, California, 1932–33*

Treatment No.	Rate per acre	Method and time	Computed yield per acre	Sucrose percentage	Apparent coefficient of purity	Calculated yield of sugar per acre†	
						Gross	Indicated as available
	pounds		*tons*	*per cent*		*pounds*	*pounds*
1	200	Broadcast before plowing	18.52	16.67	88.64	6,172	5,471
2	200	Broadcast after plowing	18.51	16.43	88.55	6,080	5,385
3	400	200 lbs. broadcast before plowing; 200 lbs. drilled with seed	24.36	16.59	88.31	8,095	7,154
4	400	200 lbs. broadcast before plowing; 200 lbs. broadcast before planting	20.69	16.30	89.10	6,732	5,992
5	400	200 lbs. broadcast after plowing; 200 lbs. drilled with seed	23.58	16.80	88.38	7,918	7,002
6	400	200 lbs. broadcast after plowing; 200 lbs. broadcast before planting	19.21	16.68	87.92	6,497	5,711
7	200	Broadcast before planting	18.37	16.69	88.27	6,121	5,396
8	200	Drilled with seed	23.20	16.53	88.31	7,693	6,775
9	0	Unfertilized check	14.23	16.41	88.87	4,660	4,147

* The experimental work was carried on in coöperation with the American Crystal Sugar Company, which provided land and other facilities for these experiments.

† Obtained by averaging sugar-per-acre values for each plot and hence differing slightly from product of the means given in this table.

FACTORS INFLUENCING THE PURITY AND SUCROSE PERCENTAGE IN THE SUGAR BEET

The weight of the root multiplied by the sucrose (sugar) percentage gives the actual weight of sugar in the root. Twenty tons of roots testing 18 per cent sugar contain 7,200 pounds of sugar. To be sure, not all this sugar reaches the bag, for in the handling and processing of the beet some of it is lost.

The grower is chiefly interested in tonnage and sucrose percentage. The processor, too, is interested in these matters but also in the "purity" of the extracted beet juice—that is, the percentage of sugar in the total dry substance contained in the juice. For example, if the beet juice upon evaporation yields 100 pounds of dry substance containing 80 pounds of sugar, the purity of the solution will be 80. Evidently in the 100 pounds cited there are 20 pounds of nonsugars, including various salts that the beet plant has absorbed from the soil, and certain organic materials such as gums and organic acids. Nonsugars in the beet juice prevent the crystallization of sugar. A larger percentage of the total sugar present can therefore be extracted from a beet of high purity than from one of low.

Purity is influenced by several factors, chief of which are the type of soil and the maturity of the beet. As a rule, low sucrose percentage is coupled with low purity; and accordingly in the contract with the grower the processor usually reserves the right to refuse beets having a sucrose percentage below 12.

Any condition of the environment that affects the growth of the plant influences the sucrose percentage of the beet. The storage of sugar in the root is dependent upon all other activities in the plant. Sugar is manufactured in the leaves, which utilize carbon dioxide gas absorbed from the atmosphere and water absorbed from the soil. Some of this sugar is used by the plant in building tissues, some is respired, and some is stored in the root. The manufacture of sugar in the leaves, the building of storage tissue, and the movement and storage of sugar all depend upon the proper functioning of the entire plant.

Again the need of balanced growth in the beet plant, of conditions that will permit uninterrupted growth throughout the season, must be emphasized. The time-honored but erroneous opinion that the beet must be made to suffer at some stage in its life in order to stimulate root growth or sugar storage should be discarded. The plant that has its normal routine of living disturbed, through any cause and at any period, is sure to suffer; and the result will be evident in decreased yield at harvest. From the day the young plant emerges from the ground and at every stage throughout the season until harvest, weight of root and sucrose percentage are being determined. If well cared for at every stage, the plant matures normally; and a properly matured beet is usually one with high sucrose percentage.

The principal factors influencing the sucrose percentage of a beet are climate, date of planting, water, cropping system, spacing, fertilizers, and injury resulting from plant diseases, insect pests, and hail.

Climate.—In sections of California where the beet crop is exposed to high temperatures for a long period, the roots are usually low in sucrose percentage and in purity. To produce high-quality beets in the hot interior valleys, it is advisable to seed early, in January or February, so that as much as possible of the root growth is made during the cooler part of the season.

Date of Planting.—As a rule, beets planted early surpass those planted lated in sucrose percentage. One reason is given in the preceding paragraph. Further, late-seeded beets are liable to be more immature at harvest than those seeded early, and consequently lower in sucrose.

Water.—According to most growers in irrigated areas, beets which have had an "early" first irrigation have a higher sucrose percentage than those which have received a "late" first irrigation—that is, an irrigation applied when at least a portion of the acreage is showing signs of distress. This interruption in growth probably explains the decreased sucrose percentage at harvest. An early first irrigation, on the other hand, means no cessation in growth and consequently a more normal development of the crop.

Irrigation is rather commonly withheld late in the season in order to "bring about ripening of the beet." A much debated question is how long the interval should be between the last irrigation and the harvest. The withholding of water undoubtedly increases the sucrose percentage in the beet, simply as a result of its drying out. But this increase is usually at the expense of a loss in tonnage and also often of total sugar. Reliable data from the irrigated sections of the United States indicate that irrigation of sugar beets can and should continue until within 14 to 21 days of harvest, although there are possibly certain coastal districts in California where the last irrigation should be earlier than this; that such late irrigations cause no depression of the sucrose percentage, provided the beets have had uninterrupted and normal development throughout the growing season; that late irrigations have an ill effect only when they start a second growth of tops, a difficulty which will not arise if all conditions have been favorable throughout the season. As a general rule, in California, irrigation is discontinued too early.

Cropping System.—Because the crops preceding sugar beets influence the available mineral nutrients, the mechanical condition of the soil, and the moisture in the soil, they affect not only the yield of roots but the sucrose percentage. In general, a great abundance of available nitrogen in the soil depresses the sucrose percentage. Beets grown on such soils make a large top growth and mature slowly. Nonleguminous green manures that add to the soil large amounts of carbonaceous material, which in turn retards the nitrifying processes there, may counteract the effect of nitrogen. In general, beets following beets without manure or commercial fertilizers are relatively high in sucrose percentage, but give unsatisfactory yields. Usually beets the second year after alfalfa with an intermediate cultivated crop have a higher sucrose percentage than beets the first year after alfalfa. In considering these relations, one should remember that an actual deficiency of nitrogen or other essential mineral elements may cause not only inferior yields but a low sucrose percentage.

Spacing or Stand.—As a rule, an increase in the soil volume in which each individual beet grows decreases the sucrose percentage. In other words, within limits, a wide stand yields beets lower in sucrose percentage than a close stand. Apparently, if the beet plant has ample soil volume in which to grow, the root and top both become large at a sacrifice of sucrose percentage; if it is crowded, its size is reduced, but the sucrose percentage is relatively high.

Fertilizers.—As stated, a great abundance of available nitrogen in the soil, whether resulting from the excessive application of barnyard manure, of green manure, or of a commercial fertilizer carrying a high percentage of nitrogen, tends to depress the sucrose percentage in the beet. This effect is especially pronounced if the high availability of nitrogen is accompanied by a deficiency of potassium or phosphorus.

Injury.—Injury from any cause—nematodes, woolly aphid, root-rot (*Sclerotium*), leaf spot, mildew, curly top, cultivation, hail, etc.—usually causes a decrease in the sucrose percentage in the beet. The rolling of beets when the leaves are too large often injures the crop permanently by reducing the food-manufacturing surface and by making the plant more susceptible to the attacks of fungus diseases.

UTILIZATION OF BEET TOPS

The value of sugar-beet tops has not been appreciated in California so fully as in those sugar-beet-growing areas where feeding of livestock is a more prominent part of the farming operation. Where diversified farming is the rule, sugar beets form an important crop in the rotation system, and the handling of beet tops so as to obtain the maximum food value from this important by-product is fully appreciated. The beet tops, consisting of crown and leaves, contain an initial moisture content of 75 to 90 per cent; and on an average there are about 300 pounds of dry matter in the tops from a ton of beets. Experiments conducted by the Colorado Agricultural Experiment Station[6] showed "that an average acre of tops is equal in feed value to a ton of alfalfa hay, and that a ton of dried tops and a ton of alfalfa hay are equal to two tons of alfalfa hay

[6] Skuderna, A. W., and E. W. Sheets. Important sugar-beet byproducts and their utilization. U. S. Dept. Agr. Farmer's Bul. 1718:1–28. 1934. (May be secured from Superintendent of Documents, Washington, D. C.; price 5 cents a copy.)

fed alone, in putting gains on steers during the first six weeks of fattening period."

The method of handling beet tops on California ranches usually consists in pasturing the tops in the field. This method of feeding is objectionable during periods of early rainfall. Considerable food is wasted, and there is also a detrimental effect caused by the livestock's packing

Fig. 22.—Spot in field infested with sugar-beet nematode. The nematode frequently appears in a field of beets in a small area and spreads, usually in the direction of the rows, by irrigation water and farm machinery.

the soil. The beet tops can be fully utilized by placing them in small shocks in the field at the time the tops are removed and later hauling them to the feed lots. Sugar-beet growers interested in the handling and utilization of sugar-beet tops and in the value of pulp and molasses as a food for livestock may secure a copy of Farmer's Bulletin 1718.[7]

CONTROLLING THE SUGAR-BEET NEMATODE

The sugar-beet nematode (*Heterodera schachtii*), one of the most destructive pests of the sugar-beet crop in southern California, is repeating here the history of crop reduction that has accompanied infestation of fields in other parts of the United States and in Europe.

Precautionary methods are necessary to prevent the nematode from entering noninfested fields. Already the beet-sugar companies have adopted appropriate practices to handle "return dirt" from beet deliveries, since infestation commonly results from the spreading of return dirt in farmers' fields. The nematode can be spread from one part of the

[7] See footnote 6, page 55.

field to another by various cultural operations, by irrigation water, by livestock, and by farm machinery. Formerly it was often spread by irrigating the fields with waste water from the beet-sugar factory, but this disposal of waste water is not generally practiced now in California.

The life history of the sugar-beet nematode has been given in full in Farmer's Bulletin 1514.[8] There are four stages in its development: the egg, the larva, the adult, and the brown cyst or resting stage. Several generations of nematodes may be completed each season in California, so that although the initial numbers may be comparatively small, the nematodes may increase enormously if conditions (moisture, temperature, and suitable host plants) are favorable. Thus a susceptible crop such as the sugar beet may be severely injured before the close of the growing season.

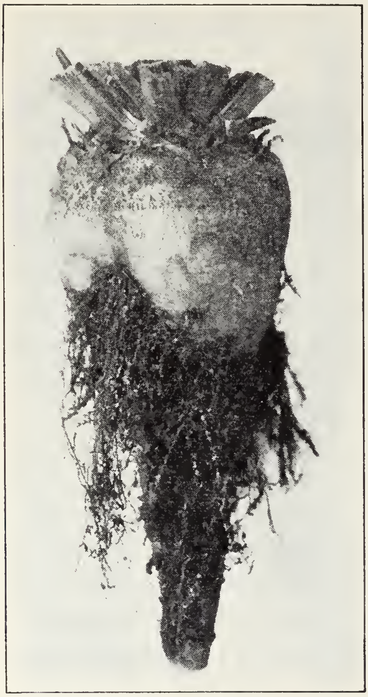

Fig. 23.—Sugar-beet root infested with sugar-beet nematode. Observe the abnormal development of lateral roots, to which are attached the whitish bodies of adult female nematodes.

The brown cyst stage is important in the life cycle; in this state the nematode may remain dormant for several years, which necessitates a strict rotation practice in which the period between successive beet crops should be at least five years.

Every sugar-beet grower should know whether or not his beet field is infested with this nematode. The presence of the pest can be best determined by thoroughly surveying the beet field during the summer when the beets are making a rapid growth. Plants attacked show a wilted condition and are usually undersized (fig. 22). A survey of the field may well follow the application of irrigation water: when the field is irrigated, the infested plants are more readily detected by their wilted condition in contrast to the turgid condition of the healthy plants. In addition, the moist soil condition permits the grower to remove the suspected plants carefully from the soil with a minimum destruction of rootlets, to which, in case

[8] Thorne, Gerald. Control of sugar-beet nematode by crop rotation. U. S. Dept. Agr. Farmer's Bul. 1514:1–20. 1926. Revised 1932. (May be secured from the Superintendent of Documents, Washington, D. C.; price 5 cents a copy.)

of infestation, small, whitish, lemon-shaped bodies (the adult female nematodes) will be found adhering (fig. 23). These bodies are large enough to be seen with the unaided eye. The field superintendents of the beet company should be called upon for assistance in these general field surveys by a grower unfamiliar with the nematode and its injury to beets.

If a field is infested, direct measures are necessary to reduce the nematode population since, if susceptible crops are continued in the field, the situation will become so serious that profitable yields of beets cannot be obtained.

A practical method of reducing nematode infestation is to withdraw infested fields from sugar-beet culture for several years and plant them with crops that are not host plants to the nematode. Any of a number of crops can be used—for southern California especially, legume forage crops, beans, peas, potatoes, small grain, corn, tomatoes, onions, peppers, and several other truck crops. The choice of crop is governed largely by the market situation and by the type of farming employed. Where a rotation of long duration is used in the farming system, alfalfa has been most frequently selected. Where this crop is not suitable, the problem of selection is somewhat difficult, since, in cases of severe infestation, at least five years should elapse between beet crops.

The alternation of a lima-bean crop and the sugar-beet crop has been profitable in the coastal area of southern California, where the climate is favorable for bean growing and where the sugar-beet nematode is absent or the infestation very light. The average yield of the sugar-beet crop grown in this sequence has been equal to the average yield of sugar beets for the area where different cropping practices were followed.

If nematode infestation becomes serious with this cropping system, as shown by the field survey of the beet crop, a lengthening of the rotation by the use of crops not subject to the nematode is necessary. For this, alfalfa is commonly employed. The results may be either highly satisfactory or entirely unsatisfactory; they depend upon a very simple relation between the nematode and its hosts.

These two types of results, obtainable in long rotations designed to starve out the nematode, can be illustrated by experiences on one of the large sugar-beet farms in southern California.[9] On certain of these farms, infestation had necessitated a systematic cropping plan for controlling the sugar-beet nematode. The cropping plan chosen consisted of alfalfa three years, barley two years, sugar beets one year, then alfalfa again, which provides five years between beet crops. As a rule the alfalfa crop was allowed to occupy the land no longer than three years. The

[9] The writers are indebted to Mr. J. W. Rooney of the American Crystal Sugar Company for making these records available.

frequent summer irrigation of the alfalfa seemed to encourage Bermuda grass (*Cynodon dactylon* L.), which in about three years had so invaded the stand of alfalfa as to render continuance in alfalfa unprofitable. The alfalfa sod under this plan of rotation is plowed under in late summer and planted in early fall to barley.

The barley grain crop is less remunerative than some of the cultivated crops grown on irrigated farms, but the cost is usually low because the barley is fall-planted, a procedure that takes advantage of the winter rainfall. Thus sufficient moisture is usually assured to mature the crop without irrigation. The barley crop has another advantage in the crop rotation on farms under irrigation, in that it matures at a time when Bermuda grass can most effectively be combated. As soon as the barley crop is harvested, the stubble is shallow-plowed in early summer, so that the roots of the Bermuda grass are exposed to drying and to summer heat. This practice greatly reduced the Bermuda grass in fields previously planted to alfalfa.

Plowing of fields in early summer, as outlined for the control of the Bermuda grass, apparently destroys large numbers of sugar-beet nematodes. When the female nematodes attached to the roots of the host plants are subjected to drying winds and to the direct rays of the sun, many are destroyed. Where this practice has been employed in connection with a cropping system made up of nonhost plants for the nematode, profitable crops of sugar beets have been produced in fields in which previously the nematode infestation was serious.

Records of beet yields before and after rotation are available for nine fields infested with nematodes. The rotation was as follows: alfalfa three years, barley two years, and sugar beets one year. The average yield of beets per acre before the rotation was 2.5 tons; after the rotation 15.0 tons.

In other fields practicing the same rotation as given above, the yield of beets decreased over a period of three years. Observations of the situation in these fields, in which control was ineffective, during the years when the crops intended to starve out the nematode were being grown disclosed the factor responsible for the failure to secure the desired nematode control on certain fields. With these particular fields, in the alfalfa crop and in the barley crop, weeds on which the nematode could live and increase were abundant. This defeated the entire purpose of the long rotation. Because of a rather sparse stand of alfalfa, numerous mustards and alkali weeds persisted in the barley. Some volunteer beet plants, growing as weeds, were also present in the alfalfa and in the barley crops. All these host plants at least maintained, if indeed they did not increase, the nematode population. When, at the close of the rotation, beets were again planted, the nematode situation had not been improved.

These contradictions to the general successful experience with long rotations in reducing nematode populations to safe proportions are therefore easily explained. The nonhost crops mentioned can be successfully used to reduce the nematode population, provided weeds are not permitted to nullify the results.

The obvious way to prevent failure in the control measure lies in maintaining good stands of alfalfa so as to reduce weed growth to a minimum. Careful preparation of the seed bed for alfalfa and planting at the proper time with sufficient seed of good quality usually gives a thick stand. In some areas in southern California where a deficiency of phosphate exists, an application of the latter material has increased the yield of alfalfa. Care must be exercised to prevent volunteer beets and weeds from growing in the barley crop.

A word of caution at this point. Having produced a profitable crop of sugar beets after such a rotation, the grower may believe that another beet crop could be successfully grown before reseeding the field with alfalfa. That such is not the case is forcefully shown by Thorne,[10] who reports the bad results of producing two successive crops of sugar beets after rotations on nematode-infested fields. This study included eight different fields that had been out of beets for periods varying from four to nine years. The first crop of beets after the rotation produced an average yield of 18.69 tons per acre, as against a 7.4-ton average yield when sugar beets were grown twice in succession on such infested fields.

Questions are often asked regarding the effect of commercial fertilizers in increasing the yield of sugar beets on nematode-infested soil, and the possibility of using such applications in place of the long rotations. Data indicate that any reasonable method of improving the fertility of the soil—provided there is not a heavy infestation of sugar-beet nematode—will materially improve beet-tonnage yields. Where a severe infestation of the nematodes exists, however, field tests show that beet yields cannot be increased sufficiently to make additions of commercial fertilizer profitable.

Fields infested with the sugar-beet nematode should not be planted with beets, but should be seeded with alfalfa or some other crop equally effective in starving the nematode. The period between successive beet crops on infested land should be at least five years, and the crops should be those not attacked by the nematode. The stands of these crops designed

[10] Thorne, Gerald. Control of sugar-beet nematode by crop rotation. U. S. Dept. Agr. Farmer's Bul. 1514:1–20. 1926. Revised 1932.

to starve the nematode must be maintained so that weeds such as mustard, alkali weed, and their allies, or volunteer beets that harbor and increase the pest, cannot get in to defeat the purpose of the cropping plan.

Once the rôle these weeds can play is recognized, and it is seen that their

Fig. 24.—*Sclerotium rolfsii,* the cause of southern sclerotium root-rot, on sugar-beet root. Note the white strands of the fungus and the small sclerotia resembling mustard seed.

entrance comes about because conditions for the crop are unfavorable, the situation can be corrected. Then the full value of long rotations for nematode control may be secured in southern California.

SOUTHERN SCLEROTIUM ROOT-ROT[11]

Southern sclerotium root-rot, caused by *Sclerotium rolfsii,* is the most serious fungus disease on sugar beets in the interior valleys of California. Although its importance has been recognized only since 1931, it evidently produced severe losses several years before this date.

The most noticeable aboveground symptom is a sudden wilting of the leaves, frequently preceded, however, by an unthrifty appearance of

[11] This section and the following one were contributed by Lysle D. Leach, Assistant Plant Pathologist in the Agricultural Experiment Station.

the plant. When a diseased plant is removed from the soil, the white, silky or cottony strands (the mycelium) of the fungus can be observed on the surface of the root and in the soil nearby. The only reliable sign of this particular type of root-rot is the presence of small, round, white or tan or brown bodies (the sclerotia) closely resembling mustard seed

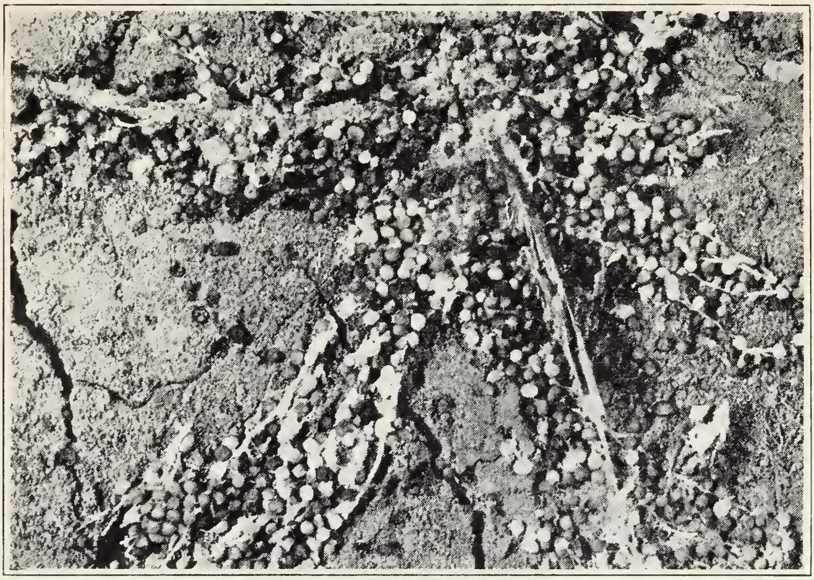

Fig. 25.—*Sclerotium rolfsii* on the roots of a morning-glory plant growing adjacent to infected sugar beets.

(fig. 24). These sclerotia, produced in great abundance on the beet root and in the soil surrounding the beet (fig. 25), carry over the fungus from one year to another.

The causal fungus thrives best at temperatures between 85 and 95° Fahrenheit, and little infection occurs when the soil temperature is below 70°. In the Sacramento Valley the usual season of activity is from May to October, but the fungus may infect plants at other times if the temperatures are unusually high.

A severe infestation on a favorable host, such as sugar beets or carrots, produces large numbers of sclerotia. As many as 5,000 sclerotia per cubic foot of top soil are occasionally found where more than 50 per cent of the sugar beets have been infected. During succeeding years, if susceptible crops are avoided, the number of sclerotia is rapidly reduced. Although there is no evidence that the fungus can be entirely eradicated from the soil by growing nonsusceptible plants, this is the only practical measure that can be recommended now for fields known to contain the fungus.

The relative susceptibility of different crops varies considerably with local or seasonal conditions, but the following general grouping can be made:

1. Crops that escape infection when grown as a winter or early spring crop: peas, lettuce, and spinach.

2. Crops nonsusceptible or only slightly susceptible: alfalfa, asparagus, hops (one year's observation), wheat, barley, corn, and related crops.

3. Crops susceptible but not severely infected under ordinary cultural conditions in central California: tomatoes and onions.

4. Susceptible crops (decreasing order of susceptibility): sugar beets, carrots for seed, potatoes, beans, lettuce for seed, cotton (seedling stage).

Although the fungus that causes southern sclerotium root-rot is widely distributed in certain areas of the Sacramento Valley, there are still many areas or fields in this Valley not known to be infested. An important phase of control is therefore to check the further spread of the fungus.

Some of the important ways in which sclerotia may be carried to uninfested fields are:

1. Movement of dirt from infested fields during beet harvesting operations, including disposal of screenings from beet dumps, and movement of trucks and agricultural machinery.

2. Movement of stecklings, bulbs, or seedlings from infested fields. Plants such as carrot, garden beet, onion, and tomato, used for transplanting, may be infected; or the adhering soil may contain sclerotia.

3. Water that drains from the surface of infested fields either during heavy rains or as excess from irrigation and is later used to irrigate clean land.

4. Livestock, such as cattle or sheep, transferred from infested to uninfested beet fields and carrying sclerotia either internally or in dirt on their feet or bodies.

During the past two years the agricultural commissioners, the sugar companies, and the sugar-beet growers have coöperated to prevent the return of screenings to field trucks and to restrict the movement of livestock.

DOWNY MILDEW OF THE SUGAR BEET

Downy mildew, caused by *Peronospora schachtii*, is a minor disease of sugar beets in California. Since the causal fungus develops abundantly only with high humidity and moderately low temperatures, the sugar-beet fields in the Sacramento and San Joaquin valleys usually show a low percentage of infection, whereas fields in the coastal districts often show large numbers of infected plants.

The most conspicuous symptom of downy mildew is the dwarfing and downward curling of the margin of the inner leaves (fig. 26). A close microscopic examination of the lower surface of infected leaves will

Fig. 26.—Beet affected with downy mildew, showing dwarfed and curled youngest leaves. Insets show the curled and malformed leaves enlarged. (From Bul. 465.)

show a dense mildew-like coating that consists of abundant tree-like spore-bearing branches protruding from the stomata (pores) of the leaf.

Infection may originate from (1) overwintering spores in the field soil, (2) wind-blown spores from nearby infected sugar beets, garden beets, or Swiss chard, and (3) possibly infected seed. Plants infected in the seedling stage may die because of injury to the growing point; but in most cases they show partial recovery with the arrival of warm, dry weather. Information from Salinas in 1930 indicated that the weight of infected beets was from 15 to 20 per cent less and the sugar yield 20 to 30 per cent less than that of healthy beets in the same field.

The most effective fungicides for preventing infection are bordeaux mixture and copper-lime dust; but, because of the slight damage in the interior valleys and the long periods of weather favorable for the development of the fungus in the coastal regions, the cost of such treatments is seldom justified.

Fig. 27.—Side view of sugar-beet top affected with curly top, showing inward curling of leaves toward midrib. (From Cir. 302.)

CURLY TOP OF THE SUGAR BEET, AND THE BEET LEAFHOPPER[12]

Curly top, which affects not only the sugar beet but also a large number of other hosts, is transmitted by the beet leafhopper, *Eutettix tenellus* (Baker). Although infectious, it is caused not by a visible organism but by what is known as a filterable virus: the disease may be produced by inoculating a plant with juice expressed from infected beets and passed through the finest porcelain filters or by inoculating with an extract prepared from infective beet leafhoppers and similarly filtered. Since, under natural conditions, the disease is not transmitted from one plant to another except through the agency of the leafhopper, all control measures now employed are based upon the relation between the insect and the disease.

Curly-Top Symptoms on the Sugar Beet.[13]—The earliest symptoms of curly top to appear on most diseased beets is an inward rolling of the lower and outer margin of the youngest leaves. Later the entire blade may show a pronounced inward curling toward the midrib (fig. 27).

A reliable and constant symptom of curly top plainly visible to the

[12] This section was contributed by Henry H. P. Severin, Associate Entomologist in the Experiment Station.

[13] For more detailed description of these symptoms see: Severin, Henry H. P. Curly-top symptoms on the sugar beet. California Agr. Exp. Sta. Bul. 465:1–35. 1929.

eye is a transparent network of minute veins (fig. 28), generally occurring on the innermost or youngest leaves of the beet. The cleared veinlets sometimes appear on the youngest leaf of the beet seedlings within two days after infection by the leafhopper. In older beets in the field this

Fig. 28.—*A*, Beet leaf showing normal venation; *B*, beet leaf showing the transparent network of minute veins usually present on the youngest leaves of curly-top beets. (From Bul. 465.)

symptom may develop in one to two weeks or more after infection, the time depending upon vigor of growth, temperature, and moisture of soil.

Another reliable and constant symptom of curly top is the roughened appearance of the lower surface of the leaves, developing usually after the veinlets have become transparent. A closer examination of this roughened condition upon its first appearance reveals numerous small elevations on the veins resembling tiny warts (fig. 29 *A*). As the disease

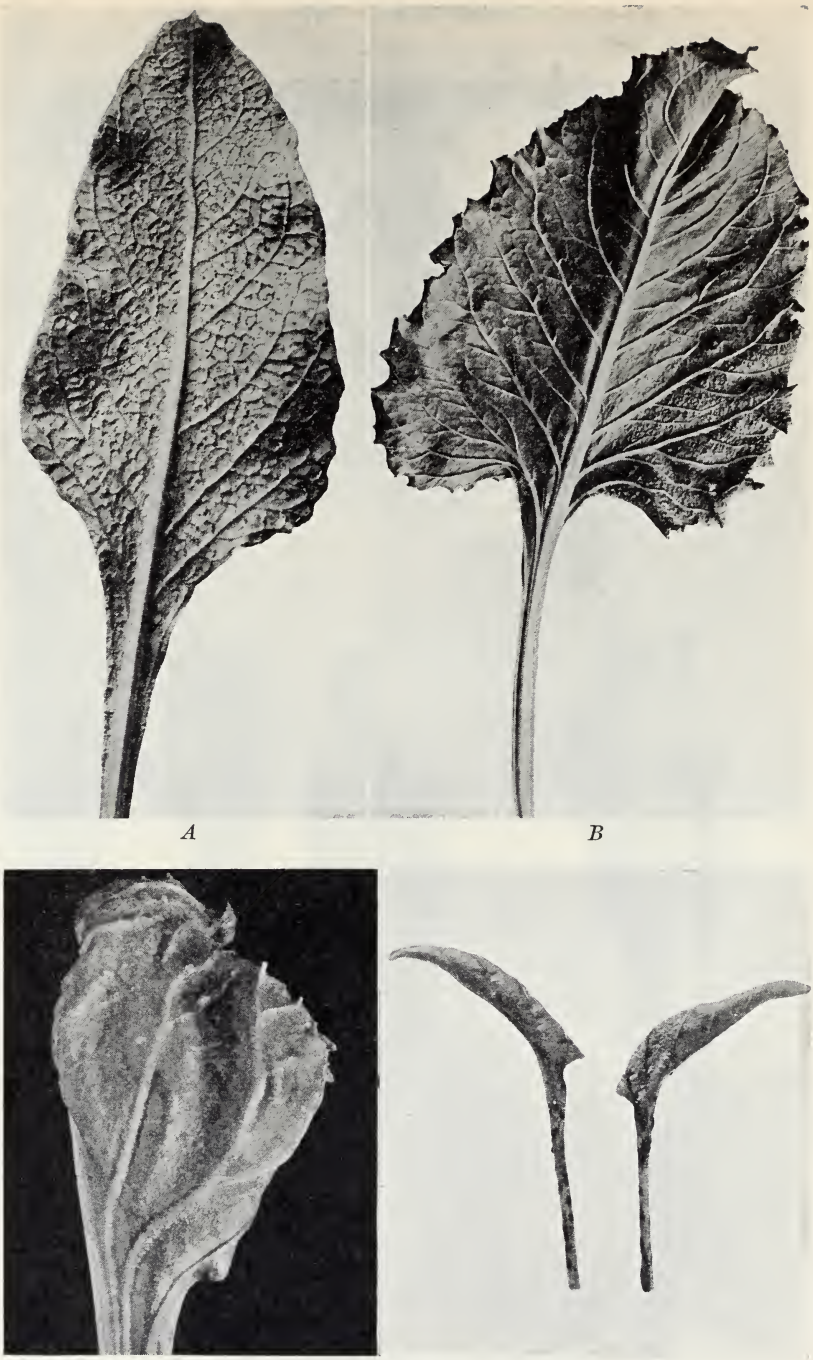

Fig. 29.—Leaves from curly-top beets showing *A*, small wart-like elevations on veins; *B*, small wart-like protuberances limited to lower right side; *C*, nipple-like papillae and knot-like swellings on distorted veins; *D*, black liquid exudation on petioles and veins. (From Bul. 465.)

Fig. 30.—*A*, "Hairy," "woolly," or "whiskered" beets with soil clinging to rootlets; *B*, "hairy" beet with soil removed, showing abundant rootlets; *C*, woody, shriveled beets that died of curly top. (From Bul. 465.)

progresses, nipple-like papillae and knot-like swellings (fig. 29 *C*) resembling galls develop here and there on the distorted veins. The diseased leaves are dark green, thick, crisp, and brittle.

When a large number of curly-top beets are examined in the field, an occasional plant may show a few drops of clear, viscid liquid exuding from the petioles, midrib, or veins on the lower surface of the leaves. Later this liquid becomes black (fig. 29 *D*) and sticky; upon drying, it forms a brown crust. This sirupy substance often oozes out of many diseased beets after the first irrigation and attracts enormous numbers of insects that feed upon the sweet drops of beet juice.

When curly-top beets are irrigated, the foliage may become green, but later the leaves often turn yellow. One should not infer, however, that the yellowing of the foliage occurs only after the fields have been irrigated; the leaves of diseased beets, especially young plants, will turn yellow without irrigation.

During very hot days in the San Joaquin, Sacramento, and upper Salinas valleys, the foliage on diseased sugar beets wilts; and the outer leaves resting on the soil become sun-scorched, turn brown, and die, only a tuft of diseased leaves remaining. Under these conditions, the beet root does not increase appreciably in size and often becomes soft and loose in the soil; it shrivels and dies, leaving a woody peg (fig. 30 *C*) in the center of a hole in the ground. Small patches of dead beets soon appear in the field, which gives a greater opportunity for other leaves to become sunburned and thus increases the size of the barren areas as the season advances.

When a badly diseased beet is pulled from loose soil, particles of soil sometimes cling to the rootlets (fig. 30 *A*) and shake off with difficulty. There is an increase in the number of rootlets (fig. 30 *B*), a condition described as "hairy root," "woolly root," or "whiskered beets." In harder soil these roots often tear off when the beet is pulled.

A cross section of a diseased beet often shows black concentric rings alternating with light circular areas (fig. 31). A longitudinal section shows the dark discoloration extending lengthwise through the beet.

Irrigation of badly diseased beets, especially when the beet roots become soft and begin to shrivel in the soil, results in rotting of the taproots (fig. 32). At the beet dumps the tareman removes the rotted portion of the beet, and the percentage of tare or dirt is, thus increased. Soft beets rot in transportation and in the bins.

The Beet Leafhopper.—The beet leafhopper transmits curly top by feeding first upon a curly-top diseased plant and then upon a healthy plant. The diseased plant which contaminates the leafhopper may be

Fig. 31.—Cross and longitudinal sections of beet affected with curly top. The transverse sections show black concentric rings alternating with light circular areas. The longitudinal sections show the dark discolorations extending lengthwise through the beet. (From Cir. 302.)

either a beet or any of a large number of weeds, ornamentals, and crop plants that are susceptible to the disease, and may be located either in the cultivated regions or in the uncultivated foothills and plains where the leafhopper overwinters.

The spring-generation beet leafhoppers, which fly into the beet fields from the plains and foothills, are pale green (fig. 33 *A*), the summer-

Fig. 32.—Curly-top beets in which irrigation resulted in a rotting of the taproot. Longitudinal and cross sections of rotted beets are shown on the right. (From Bul. 465.)

generation adults (fig. 33 *B*) may also be pale green or may be light gray or straw-colored, while the overwintering-generation adults have dark markings on the wing covers (fig. 33 *C*). The adults are about ⅛ inch in length.

Since the insects do not eat the leaves but only suck the juice, they cannot be controlled by spraying the plants with poison sprays; and the leafhoppers fly long distances so that it is impractical to attempt killing them on individual ranches. Other measures must therefore be resorted to.

Recommendations on Planting Time of Sugar Beets to Avoid Curly Top in Natural Breeding Areas.—The following planting schedule of sugar beets in the San Joaquin Valley and the interior regions of the Salinas Valley usually insures a profitable crop even during a severe outbreak of the beet leafhopper. This schedule is related to the spring and autumn dispersal of the insects in natural breeding areas such as occur in these valleys.

In natural breeding grounds most of the insects leave the cultivated areas and fly to the foothills during the autumn. This fact has an important bearing on the time of planting beets. Commercial beet seed, if used, should be planted in December and January in the San Joaquin and interior regions of the Salinas Valley, as early as weather condi-

A *B* *C*

Fig. 33.—The beet leafhopper, which transmits the curly top of the sugar beet: *A*, adult of the spring generation without markings on the wing covers; *B*, adult of the summer generation; *C*, adult of the overwintering generation with dark-brown areas on the wing covers. (About seventeen times natural size.)

tions will permit. The spring dispersal from the uncultivated plains and foothills into the cultivated areas usually occurs in April, but varies from March to May. In some years flights begin in March; in others, not until May. If late spring rains occur in the foothill areas, a partial second brood develops, and flights may continue into June. Beets attain some resistance to curly top with size and thrifty growth; and, if the foliage of sugar beets covers the row at the time of the invasion of the pest, a good crop can usually be obtained. December and January planting, however, does not give complete protection against curly-top damage in the San Joaquin and Salinas valleys, as was evident during 1919, when over half the beet crop was infected with curly top by the overwintering leafhoppers that remained in the cultivated areas.

A special variety of sugar beet developed by the United States Department of Agriculture is resistant to curly top. Seed of this variety grown in this country is now available in some quantity and should be used for planting in the interior regions or where there is exposure to curly-top damage. Since the first selections of this resistant variety had a greater tendency to bolt or form seed stalks than most commercial varieties, this seed should not be planted before February 1. Later selections from this curly-top resistant stock, now being increased, have improved resistance; and the bolting tendency has been reduced to normal. As this resistant variety becomes available in greater quantity, it will be more widely used because of the measure of protection it affords against the uncertain and often unpredictable migrations of the beet leafhopper.

Planting in Migratory Breeding Areas.—In the Sacramento Valley the overwintering beet leafhoppers apparently are exterminated. No case of curly top has ever been observed in the early-planted beet fields before the migratory flights occurred. During 1927 and 1928, beets were planted in November; but no curly-top beets were found until after the spring migration began. Early planting from November to the middle of February insures a crop in the Sacramento Valley during an outbreak of the pest. During the serious outbreaks of the leafhopper in 1919 and 1925, beets planted in March and April were destroyed by curly top. In 1925 beets planted after the migratory flights ceased in May made a marketable crop. Small migratory flights into the Sacramento Valley sometimes occur in April, but the large flight usually takes place in May. In years between outbreaks of the pest, beets planted during March and April in the Delta districts usually make good tonnages. If early planting is practiced year after year in the Sacramento Valley, a marketable product will be harvested; on the other hand, if late planting during March and April is adopted year after year, serious losses will be sustained when large migrations of the pest occur.

Planting in Fog Belts.—In the fog belt, planting with commercial seed should be discontinued from March 1 until after the spring flights cease. In the fog belt of the Salinas Valley, plantings in May and June after spring flights are completed usually result in a satisfactory crop. In 1925, however, the late plantings were badly diseased because a second brood developed on the foothills.

Fungus diseases reduce the number of overwintering leafhoppers and spring migrants in the fog belt in favorable years.

Control of the Leafhopper.—Three general lines of attack have been followed in attempts to control the beet leafhopper in central California.

The first is direct control by spraying (fig. 34), based upon the fact that the leafhoppers are forced to congregate in large numbers upon vegetation in dry washes during the autumn. The Spreckels and Holly Sugar companies have carried on this work for four years, under the direction of E. A. Schwing and Ward Waterman, in coöperation with workers of the United States Department of Agriculture at the Modesto

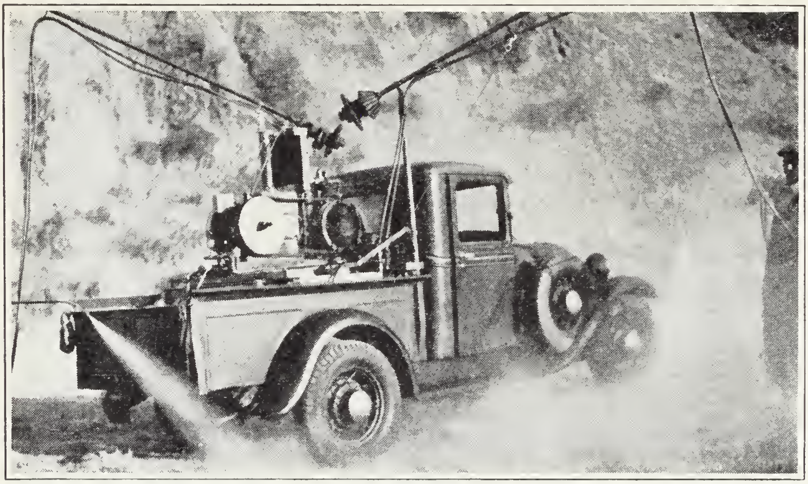

Fig. 34.—Spray equipment used to control the beet leafhopper on perennials growing on the uncultivated plains and foothills. (Courtesy, E. A. Schwing, Spreckels Sugar Company.)

Laboratory. In this work a total of 15,288 acres of perennials have been sprayed, or an average of nearly 4,000 acres per season.

The second and third methods are indirect, aiming to control leafhoppers by destroying their summer host plants. In one method the principal host, Russian thistle (*Salsola kali tenuifolia*), is destroyed by summer hoeing, dragging, or disking. This work is done before the autumn generation matures, and results in complete elimination of the leafhopper population as well as destruction of the host plant. The sugar companies have eliminated over 1,000 acres per year in 1931, 1933, and 1934 by this method. This work is rather slow and expensive and has been confined to critical areas near the foothills.

The third method aims at ultimate elimination of the Russian thistle through preventing spread and reducing the seed supply. This consists of burning the mature thistle stands late in the autumn before the plants are torn loose and start rolling. This work has been done with relief labor under the direction of the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture and the California State Department of Agriculture. In 1933, about 5,000 acres[14] were burned in San Joaquin, Stanislaus, and Fresno counties, and in 1934 about 3,000 acres in Stanislaus and San Luis Obispo counties. These last two counties are now relatively free from Russian thistle and the populations of leafhoppers correspondingly low. Some further cleanup

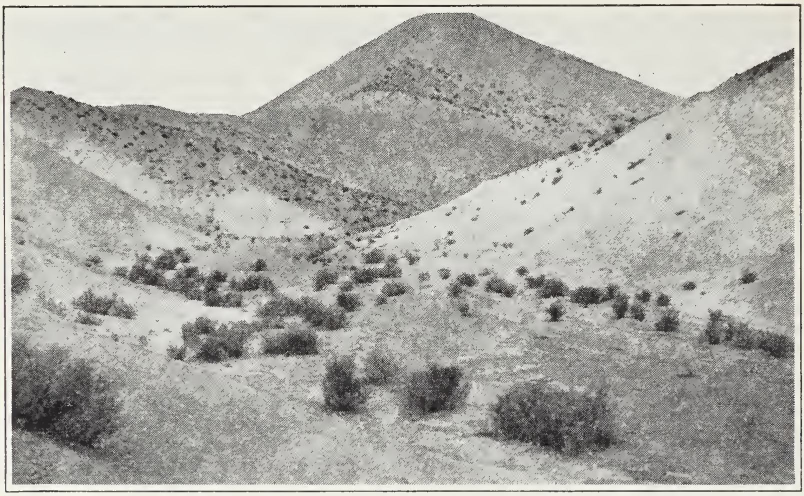

Fig. 35.—Cattle spinach, or allscale (*Atriplex polycarpa*) growing in Tunney Gulch, San Joaquin Valley. This shrubby perennial saltbush is one of the most favorable food plants of the overwintering generation of beet leafhopper. It is green during dry autumns. (Courtesy, E. A. Schwing, Spreckels Sugar Company.)

work will practically eliminate Russian thistle in Stanislaus County. This work has resulted in a greatly reduced autumn population of leafhoppers in the foothills to which this area contributes, and in a corresponding reduction in the spraying necessary in that part of the foothills.

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[14] Based on information supplied by W. C. Cook, in a typewritten report on the 1933 leafhopper control program, dated March 7, 1934, issued by the United States Department of Agriculture, Bureau of Entomology, Division of Truck Crop Insect Investigation, Modesto, California.

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